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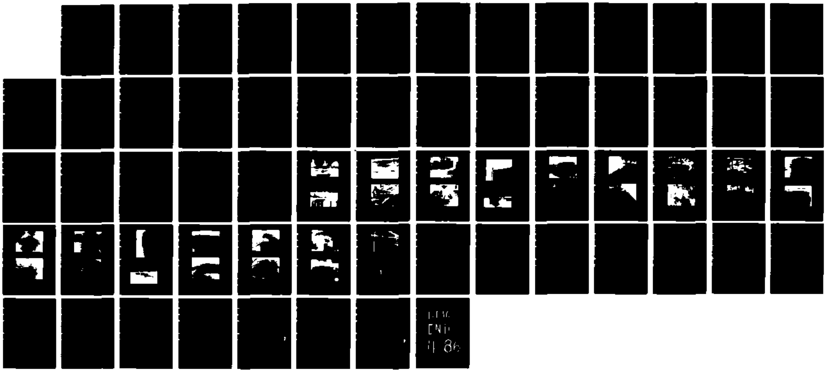

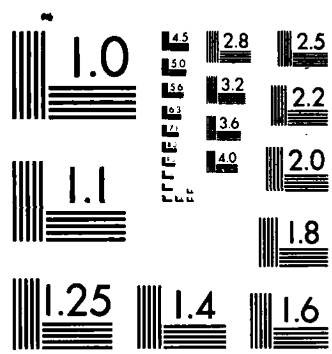

MICROCOPY RESOLUTION TEST CHART
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Technical Note

January 1986
By Spencer R. Conklin,
Daniel A. Zarate,
and Robert L. Alumbaugh
Sponsored by
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Engineering Command

Experimental Polyurethane Foam (PUF) Roofing Systems-III: Naval Station, Roosevelt Roads, Puerto Rico, and Naval Facility, Cape Hatteras, North Carolina

ABSTRACT This report presents information on field investigations of experimental polyurethane foam (PUF) roofing systems installed at the Naval Station, Roosevelt Roads, P.R., and the Naval Facility, Cape Hatteras, N.C. The roof systems at Roosevelt Roads included three different foams applied at two thicknesses, five protective coating systems applied at thicknesses recommended by their manufacturer, and two different mineral roofing granules applied in the wet topcoat. The majority of the housing units were coated with acrylic and silicone coating systems, but urethane/hypalon, modified urethane, and butyl/hypalon elastomeric coating systems were also used. The roofing system installed on the Galley at Cape Hatteras was an acrylic elastomer coated PUF roof applied over a modified bitumen membrane. At Roosevelt Roads, the butyl/hypalon-coated system weathered the best. Energy consumption at Roosevelt Roads decreased at most only 12 to 13% after foaming the roofs. The mineral roofing granules improved weathering characteristics for the acrylic systems but not the silicones. At Cape Hatteras, one-half of the acrylic-coated roof weathered very well, while the other half showed extensive blistering.

NAVAL CIVIL ENGINEERING LABORATORY PORT HUENEME CALIFORNIA 93043

METRIC CONVERSION FACTORS

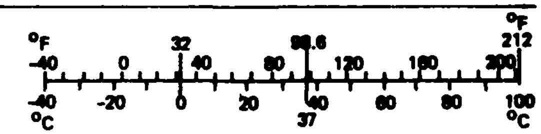
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2,000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1,000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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This report presents information on field investigations of experimental polyurethane foam (PUF) roofing systems installed at the Naval Station, Roosevelt Roads, P. R., and the Naval Facility, Cape Hatteras, N.C. The PUF roof systems were installed on 51 military family housing units at Roosevelt Roads. These roof systems contained a number of experimental variables including three different foams applied at two thicknesses, five protective coating systems applied at thicknesses recommended by their manufacturer, and two different mineral

continued

20. Continued

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This report presents information on field investigations of experimental polyurethane foam (PUF) roofing systems installed at the Naval Station, Roosevelt Roads, P.R., and the Naval Facility, Cape Hatteras, N.C. The PUF roof systems were installed on 51 military family housing units at Roosevelt Roads. These roof systems contained a number of experimental variables including three different foams applied at two thicknesses, five protective coating systems applied at thicknesses recommended by their manufacturer, and two different mineral roofing granules applied in the wet topcoat. The majority of the housing units were coated with acrylic and silicone coating systems, but urethane/hypalon, modified urethane, and butyl/hypalon elastomeric coating systems were also used. The topcoat of all coating systems was white, except for the modified urethane, which was aluminum. Eighteen units had electrical meters installed to determine energy savings associated with the foam roof installation. The roofing system installed on the Galley at Cape Hatteras was an acrylic elastomer coated PUF roof applied over a modified bitumen membrane. This report presents results of the experimental PUF roofs after 4-1/2 to 5 years. At Roosevelt Roads, the butyl/hypalon coated system weathered the best. Energy consumption at Roosevelt Roads decreased at most only 12 to 13% after foaming the roofs. The mineral roofing granules improved weathering characteristics for the acrylic systems but not the silicones.

CONTENTS

A-1

INTRODUCTION

Since 1973, the Naval Civil Engineering Laboratory (NCEL) has conducted extensive investigations of sprayed polyurethane foam (PUF) roofing systems (Ref 1 through 8). Initial investigations involved experimental field studies at the Naval Reserve Center, Clifton, N.J. (NRC Clifton) (Ref 1 and 2), small scale studies and laboratory studies at NCEL (Ref 3 through 5), and fire tests of PUF roof systems applied directly to metal decks at the Underwriters Laboratories (Ref 6). Other NCEL documents provided guidance on how to use and apply sprayed polyurethane foam roofing systems (Ref 7 and 8). The excellent insulating characteristics and potential energy conservation when used as a roofing system made the PUF materials most attractive. However, the long term weathering durability and the maintenance costs of these systems under field conditions in varying climates was of considerable concern.

Results of the initial field experiments at NRC CLifton, a colder weather area during the winter months, showed a 54% reduction in the amount of natural gas used for heating in the 8 years following application of the experimental PUF roofs (Ref 2). This study also showed that PUF roof systems with appropriate elastomeric coating performed very well over this period with only minimum maintenance. Maintenance of PUF roofs were investigated in detail and preliminary guidelines were presented in Reference 5.

It was desired to determine potential energy savings in other climates where electricity for air conditioning is a major family housing expense. Weathering performance of PUF systems in milder climates was also of considerable interest. This document reports findings, conclusions, and recommendations resulting from field inspections of experimental systems installed on roofs at the Naval Station, Roosevelt Roads, P.R., and the old Naval Facility, Cape Hatteras, N.C.

This is the final planned report covering the full scale field experiments on PUF roof systems at Roosevelt Roads, P.R., and Cape Hatteras, N.C. The results and recommendations of this effort were used in the preparation of NFGS 07545 (July 1984), Sprayed Polyurethane Foam (PUF) for Roofing Systems; the revision of NFGS 07540, Fluid-Applied Elastomeric Coating over Polyurethane Foam (PUF); the revision of MO-113, Inspection, Maintenance and Repair of Roofing Systems; and will be used in the revision of DM 1.5, Roofing and Waterproofing.

In addition to this report, an update of TN-1496 (Ref 3) is near completion. This update will provide performance information on PUF roof systems exposed on small scale laboratory specimens (2 feet by 4 feet in size) at three different exposure sites. Results of the update will complement the information contained in this current report in that it will include additional performance data on PUF roof systems reported herein. Finally, a User's Guide for Polyurethane Foam (PUF) Roof Systems has been prepared and will be available soon.

BACKGROUND

During the past 10 years, there has been increasing emphasis to improve the energy efficiency of buildings by adding additional insulation. In building roofs, this has been accomplished by increasing the thickness of the insulation in built-up roof (BUR) systems and the resultant R-value. Concern was expressed within the roofing industry that additional insulation beneath the BUR membrane would shorten its life. Theoretical and experimental data have shown that membranes applied over insulation with higher R-values tend to develop somewhat higher temperatures (Refs 9 and 10). However, there has been no experimental evidence that this has been the cause of early failure of BURs. These failures result from a number of causes but mostly involve improper materials and poor workmanship.

The many problems with conventional roofing and the excellent insulating characteristics of PUF led to NCEL's original investigation of polyurethane foam as an alternative roofing material. The first of the investigations involved the experimental PUF systems already mentioned at NRC Clifton. This was the first of several cooperative programs with the Engineering Field Divisions of the Naval Facilities Engineering Command (NAVFAC).

Sprayed PUF roof systems were first applied in the early to mid-70s at Roosevelt Roads, where blistering of the foam from the substrate and early coating failure were occurring. This led NCEL and the Atlantic Division (LANTDIV) of NAVFAC to develop a cooperative experimental program to determine causes and remedial actions.

Commander Oceanographic Systems Atlantic (COMOCEANSYSLANT) was experiencing problems with roofs on their facilities because of widely varying climates throughout the Atlantic Ocean area. In 1976, COMOCEANSYSLANT tasked NCEL to test experimental roofing systems at the Naval Facility, Cape Hatteras, N.C., located adjacent to the Atlantic Ocean on the outer banks of North Carolina.

EXPERIMENTAL PUF ROOFING SYSTEMS

Naval Station, Roosevelt Roads, P.R.

During the period from late 1978 to early 1979, various PUF roofing systems were installed on 51 houses as part of a station contract for roofing military family housing. The cooperative program developed at NCEL was designed to determine the effects of varying experimental parameters. These included three different polyurethane foam materials applied at two different thicknesses, five different types of coating systems applied at different coating thicknesses, and two types of mineral roofing granules. One of the granules was specially treated to give them fungicidal properties.

Electric meters were installed on 18 houses to determine comparative electrical power usage. Twelve meters were installed about 8 months before the units were foamed, while the other six meters were installed after foaming. The NRC Clifton test site demonstrated that applying a PUF roof system provided a 54% reduction in heating with natural gas

(Ref 2). It was desired to determine potential electrical energy savings for air conditioning resulting from application of PUF roofs in a tropical environment.

Table 1 provides details on the various PUF roofing systems applied to the 51 housing units, and this information is summarized in Table 2. Additional details on the PUF, the coatings, and the granules are presented in Appendix A. Each variation of a given PUF roof system was applied to three separate housing units. The foam on most of the housing units was specified at 1-1/4 inches thick but in many cases was applied 2 to 3 inches thick. The foam thickness on six units, one group coated with acrylic and the other with the silicone systems, was specified to be 3 inches thick. In many cases, the foam thickness was 4 to 6 inches thick. The 1-1/4- and 3-inch foam thicknesses were specified to determine the optimum foam thickness for maximum energy conservation.

The majority of housing units were coated with either acrylic or silicone elastomeric coating systems, the most commonly used coating systems at the time the cooperative tests were designed. The foam thickness, coating thickness, and use and type of mineral roofing granules were varied only in those groups coated with these two coating systems. The other three coating systems were each applied to only to one group of (three) housing units in which the foam thickness was specified at 1-1/4 inches, and none were surfaced with mineral roofing granules.

Figure 1 depicts a typical family housing unit included in the experiment. Roof decks are low-slope structural concrete in all cases. Houses are located in a semi-tropical environment near the sea shore with tropical landscaping - including numerous palm trees and dense shrubbery.

NCEL and LANTDIV personnel visited and inspected the family housing at Roosevelt Roads in late 1976. NCEL developed experimental plans for the cooperative tests in early 1977, and plans and specifications were prepared by the LANTDIV Design Division. As noted above, the experimental roofs were applied in late 1978 and early 1979. The application was monitored by personnel from the office of the Resident Officer in Charge of Construction (ROICC).

NCEL inspected, rated, and photographed 31 of the PUF roof systems in September 1979 (approximately 1 year after application) and all 51 of the roofs in March 1983 (approximately 5 years after application). Random samples of the protective coatings were taken for laboratory examination; the coating thicknesses determined by microscopic examination are given in Tables 1 and 2. Results of the two inspections are given in Table 3 and summarized in Table 4.

Naval Facility, Cape Hatteras, N.C.

Five different types of roofing systems were selected by NCEL for the Cape Hatteras tests. Only one of these was a sprayed-foam system, and its performance is reported here. The buildings at the Cape Hatteras site were small, single story units of concrete block. The roof decks were essentially flat, consisting of gypsum concrete planks supported by steel bar joists. The existing roofs were gravel-surfaced, built-up roofs applied over 1 inch of insulation, hot mopped to the gypsum plank. Figure 2 shows an overview of the old BUR on the Galley.

The sprayed foam roof was a variation on a conventional PUF roof called Energy Efficient Rated Roofing System (EERRS) and covered by U.S. Patent No. 4,016,323. The variation consisted of applying a self-adhering membrane (SAM) to the roof deck and spraying the foam on the SAM, rather than directly on the roof deck. The SAM is a modified bitumen membrane with adhesive backing applied during manufacture. This system was applied to the Galley. The as-built drawings showed that the BUR was constructed as described above, i.e., the insulated BUR was applied directly to the gypsum plank roof deck. The contract specifications called for tearing off the old roof down to the gypsum plank, priming the roof deck, and attaching a self-adhering membrane (Material D, Appendix A) to the primed deck and the edge flashing (foam stop). The SAM served a dual purpose. First, the SAM provided a rapid means of waterproofing the roof that could be installed more rapidly than the PUF roof or a BUR. Second, the SAM provided a good vapor retarder on a roof deck over a high humidity area, the Galley.

When the old roof was torn off, the insulation was attached to a poured gypsum concrete roof deck rather than gypsum plank. Because of this, the SAM was adhered directly to the poured gypsum concrete and the foam stop rather than the gypsum plank and the foam stop (Figure 3). The western portion of the gypsum concrete deck was subjected to an unexpected rain storm after the BUR was removed and before the SAM was attached. This caused substantial leaking and wetting of the gypsum concrete. The SAM did not adhere well to the gypsum concrete in one area because it was damp. Figure 4 shows a workman removing the SAM (with PUF attached) from the gypsum concrete in the area before the repairs.

The 2-1/4 inches of PUF were applied directly to the SAM (Figure 5). The foam was A4 (see Appendix A), which was similar to foam A1 used at Roosevelt Roads except that the density was 2.5 lbs/ft^3 and the compressive strength was 42 psi. The elastomeric coating system was the same acrylic elastomer as that used in the Roosevelt Roads tests, B1, and was applied in three coats to a minimum dry film thickness (DFT) of 25 mils (Figure 6). Mineral roofing granules were sprinkled into the wet topcoat at the rate of 45 pounds per square. Additional information on the materials used is provided in Appendix A. The PUF roof system was applied during the latter part of 1978. Personnel from the U.S. Army Construction Engineering Research Laboratory (CERL) monitored application of this roof as part of their research on roofing systems, and some of the figures were supplied by them.

After the PUF roof system was installed, the foam started to separate from the flashing around the perimeter of the roof. One section of the roof perimeter was repaired by removing the loose foam and refoaming that area. However, the separation occurred again, and additional separations also occurred in other areas. The roofing contractor investigated the problem and suggested that the SAM was pulling away from the edge because it had not been mechanically attached. As the membrane pulled back from the edge, the foam also was pulled away (See Figure 7). The roofing contractor solved the problem by removing the foam and membrane completely from about 1 foot back from the flashing around most of the roof's perimeter. That area was then refoamed using 5 lb/ft^3 density foam and recoating with the acrylic elastomer coating (See Figure 8).

RESULTS AND DISCUSSION

Roosevelt Roads, P.R.

General Evaluation. The condition and performance of the experimental roofing systems were determined by walking all areas of each roof, noting and photographing defects or deterioration in the protective coating and the polyurethane foam, and assigning weathering performance ratings. Coating system defects included: visible pinholing, flaking, blistering, peeling, bird pecking, chalking, erosion, and cracking. Foam defects included: blistering, delamination, degradation, and erosion.

The roof system of each of the units was rated individually and these ratings are given for the 1- and 5-year exposure periods in Table 3 and summarized for each of the coating systems in Table 4. Ratings were assigned on the following basis:

E = Excellent; the system is in excellent condition with little or no coating or foam deterioration.

VG = Very good; the system is performing very well and shows only minor coating or foam deterioration (i.e., less than 5%). Minor annual maintenance will usually extend the time before more extensive maintenance is needed.

G = Good; the system is performing satisfactorily but coating or foam deterioration is nearing a point (i.e., less than 10%) were minor repairs should be carried out in the near future to prolong the need for total recoating.

F = Fair; the system is showing moderate coating or foam deterioration (i.e., greater than 10%). Moderate repairs, including recoating, may be required in the near future to prevent more severe deterioration.

P = Poor; the system has numerous areas showing moderate to severe coating or foam deterioration. Major repairs, such as scarfing, adding foam, and recoating are required to prevent total system failure. In the most severe cases, replacing the total system may be required.

The inspections showed that some of the deterioration was directly attributal to physical abuse. This included punctures from installing roof-mounted television and radio antennas (see Figures 9 and 10). Such abuse was present on at least 35% of the units. Also, considerable damage was caused by tree limbs rubbing on the roofs (see Figures 11 and 12) and plants growing in the foam where excessive amounts of leaves and debris had accumulated (see Figures 13 and 14). Although the severity of these kinds of damage in many cases required major repair or replacement, the ratings did not take into account this physical abuse. Although PUF roof systems can be more vulnerable to physical damage than other roofing systems, all roof systems, including built-up roofing or single-ply roofing, will suffer from such abuse.

The following paragraphs provide information on various areas where system defects were observed and discuss the performance of the roofs according to the generic types of coating systems.

Flashings. Steel angle iron supports for solar collectors were installed after the PUF systems had been applied. In nearly all cases, the silicone coated PUF applied by the solar contractor as flashing around each leg support was in excellent condition. The silicone coating had been generously applied, overlapping the adjacent acrylic coated surfaces (See Figure 15). The silicone coating bonded well to the acrylic elastomer coating and appeared completely compatible.

By contrast, most PUF flashings around other vertical projections or penetrations (pedestals for electric service drops, pipes, etc.) were defective as shown in Figures 9, 16, and 17. The foam was not properly applied to form a smooth transition from the roof deck up and around the projections or penetrations. In addition, the rougher foam surface was not coated to a proper dry film thickness to provide adequate protection. The foam around penetrations should be coated with at least two additional coats of elastomeric base coat or with a compatible caulking compound in order to protect the PUF from weathering. This was done around the angles of the solar units but not around the other penetrations or projections.

The eyes for fastening guy wires for TV antenna masts to the concrete deck were foamed over. Consequently, any movement in wires from the wind or by occupants when taking the mast down damaged the coating and the foam. ANTENNAS SHOULD NOT BE PLACED ON THE ROOF; however, in the few cases where this might be necessary, fastening brackets should be replaced so connecting guy wires would take place above the level of the PUF roof system.

Bird Pecking. Damage from bird pecking was minimal. Yearly inspections and concurrent caulking of holes should control this problem. Using newer and tougher urethane elastomer coatings and mineral roofing granules on coatings that are less tough can also help control bird pecking problems.

Terminations at Roof Edges. All systems showed some deterioration where the PUF was "feathered" or tapered off about 18 inches from the edges of the roof. Figure 18 shows the typical mildew attack along the feathered edge after 1 year of weathering. This condition became more severe with continued exposure, and deterioration of the foam and coating often occurred. The cost of properly maintaining this thin vulnerable part of the system would probably far exceed any initial savings possible from not foaming out to a foam stop at the edge of the roof. Future repairs should include (1) cutting away the deteriorated area to expose good quality, well bonded foam, and (2) brush coating the cut foam surfaces with a double thickness of protective coating extending out to the edge of the roof deck.

System Evaluations

System 1 - Acrylic. About 60% of the acrylic coated foam roofs had a 5-year overall rating of good or better, even though none of the protective coating systems appeared to meet the 30-mil minimum DFT specified for the two coat system. Thicknesses of samples taken from 11 of the 21 roofs in this group averaged only about 13 mils DFT, less than half that required. Systems with mineral roofing granules embedded in the topcoat performed better as a group than those without the granules (see Figures 19 and 20); most of the systems rated poor to fair did not have the granules (see Tables 3 and 4). Roofs with fungicidal granules were generally lighter in color and were rated somewhat higher in overall performance than roofs with regular granules.

In several of the units, the acrylic coating had blistered and cracked. However, differences were not noted with the two foams used. The surface texture of the foam on all units was "verge-of-popcorn" or smoother.

Half of the roofs in this group had been subjected to some type of physical damage and had puncture patterns as shown in Figures 21 and 22. These punctures may have been caused by the mast of a TV antenna or other conduit like pipe. Bird pecking was not a problem with this system and was observed only on one of the units. Abrasion damage by tree limbs was noted on six of the units, and nearly half of the units had excessive accumulations of dead leaves from overhanging trees as shown in Figures 11, 13, and 14. Such accumulation of leaves and other debris can deteriorate any roofing membrane because the retention of moisture in the debris promotes gradual deterioration of the membrane and plant growth. The roots of plants often penetrate the membrane, allowing water to seep into the insulation. Debris, tree limbs, and other foliage should be removed during an established maintenance program.

Deterioration and mildew growth were prevalent where PUF systems were terminated about 18 inches from the edges of the roofs (see Figures 18 and 23). Had the PUF systems been terminated along the roof edges by overlapping the protective coating onto the concrete roof deck at least 4 to 6 inches, this defect would probably not have occurred.

System 2 - Silicone. Slightly over half of the 21 PUF systems coated with silicone were given an overall rating of good or better after 5 years of weathering (see Figures 24 and 25). The silicone systems with mineral roofing granules in the topcoat, unlike the acrylics (System 1), did not perform as well as those without granules (see Table 4). The systems with the fungicidal granules performed better than systems with regular granules and four of the six systems with fungicidal granules were rated good.

The poorer performance of the silicone systems appears associated with the lack of coating thickness. The specification called for two different coating thicknesses both to be applied in two coats. The first group of units was to have a minimum DFT of 15 mils while the second was to be 22 mils. The DFT of coatings measured from random samples of seven systems was again less than specified. Based on the random sampling, the systems specified at 15 mils DFT averaged only 8-9 mils while those specified at 22 mils DFT averaged only 15 mils. When granules are embedded in silicone coatings at less than minimum thickness, performance is

diminished rather than enhanced because the granules tend to cause breaks or holidays in the membrane. Results of these tests provide further evidence that the minimum DFT of 30 mils recommended by NCEL is required to assure proper performance. Further, when granules are specified, they should be embedded in the topcoat only after two coats of the silicone with a minimum DFT of 20 mils have been applied.

In general, defects on the silicone systems were comparable to those found on roofs coated with System 1 acrylics. Blistering and cracking of the coating were noted on 14 of the 21 units, a somewhat higher percentage than noted on the acrylic roofs. Foam surface texture was slightly better than with System 1, with 20 of 21 units having a surface texture of coarse orange peel or smoother.

Physical abuse of the silicone coatings was more severe than with the acrylic systems. Palm tree abrasion, such as that shown in Figure 12, occurred on 10 of the 21 roofs, again somewhat higher than with the acrylics. Bird pecking, although not a serious problem, was observed on six of the units. The silicone-coated PUF flashing seals around legs of solar collector supports were in excellent condition, which again shows that the system will perform very satisfactorily when properly coated (see Figure 15).

System 3 - Catalyzed Urethane/Hypalon. This system on all three units was rated fair to good, which was somewhat less than the rating of the silicone in System 2. This poorer performance was attributed primarily to the lack of sufficient coating thickness in some places and heavy fungal growth in the rough, "verge-of-popcorn" surface texture of the PUF (Figures 26 and 27). The surface textures of the three roofs varied from popcorn to coarse orange peel.

The contract specification required 15 mils DFT of catalyzed-urethane base coat and 5 mils DFT of hypalon topcoat for a total system DFT of 20 mils. The coating thickness varied from 8 to 25 mils DFT depending mostly on the surface texture; the average thickness was about 14 mils DFT. The roof with 25 mils DFT was in good condition. In areas where the coating was unacceptably thin (15 mils or less), severe pinholing and chalking were observed. Hypalon by nature tends to chalk rather heavily, so this was not unexpected.

Because of its toughness, this system was much more resistant to physical abuse than either the acrylic or silicone systems. There was no evidence of bird pecking or TV mast puncture, and only one unit showed any evidence of puncture (Figure 27) or tree limb abrasion.

Although there were only three houses involved, this type of system appears to have good potential if properly applied over a smoother surface texture such as coarse orange peel or better. This particular system is no longer available as an off-the-shelf item. However, any quality, catalyzed, aromatic urethane base coat with either a hypalon or a catalyzed, aliphatic urethane topcoat should perform well. Adding fungicidal granules, although not usually required over the urethane systems, could have increased the effectiveness of the system. A catalyzed aromatic/aliphatic urethane system with granules has performed very well at the NRC, Clifton test site (Ref 2). It should be noted again that granules should only be applied to the wet topcoat after a required minimum dry film thickness has been obtained with base and intermediate coats.

System 4 - Catalyzed Modified Urethane. This system was to consist of 40 mils DFT of catalyzed, modified-urethane base coat and approximately 8 mils DFT of catalyzed, aluminum-pigmented, modified urethane topcoat for a total DFT of 48 mils. Samples that were taken ranged from 8 to 35 mils total DFT. This system exemplifies the fact that an unsuitable and inadequate coating system applied below the minimum acceptable dry film thickness can result in complete failure of the total PUF roof system. Degradation of the system was noted after less than 1 year of weathering. After 5 years of exposure, half of the coating had crazed, peeled, and disappeared, leaving the foam exposed and degraded to a dark brown color.

All three units showed evidence of coating cracking, holes, punctures, and severe abrasion by tree limbs (see Figures 28 and 29). No bird pecking was observed. The foam surface texture ranged from popcorn to orange peel. Despite the system failure and formation of pockets of rain water, no leaking occurred. No repair methods appeared feasible and completely removing and replacing of this system was required on all three units.

System 5 - Catalyzed Butyl, Hypalon. This system on all three test units was in very good condition; the overall ratings ranged from good to excellent. This system was judged best of the five systems tested (see Figures 17, 30, and 31). Some bleeding of the base coat into the topcoat occurred on one unit, probably because the topcoat was applied before the base coat had cured. This was the only defect noted on this system and did not appear to affect the coating's performance. The foam's surface texture was very good ranging from coarse orange peel to orange peel or smoother.

The specification called for 19 mils DFT of butyl base coat and 4 mils DFT of hypalon topcoat for a total DFT of 23 mils. Sample cuts indicated compliance with the 23 mils. This excellent coating performance again emphasizes the need for applying the coatings to the minimum acceptable thickness specified.

Electrical Consumption at Roosevelt Roads. The units in which meters were installed are listed in Table 1. One of the 18 units had an electrically heated kiln that used a disproportionate amount of electricity and this usage was not affected by application of the PUF. As a result, these data were not included in the compilations used to determine energy savings.

Meter readings were taken on each of the 17 units on a monthly basis by the Public Works Department, Naval Station Roosevelt Roads, P.R., and the data forwarded to NCEL. Monthly electrical consumption readings for the 17 units included in the study are presented in Appendix B for 28 months, and a synopsis is presented in Table 5.

Units 2B to 2F were foamed before having meters installed while units 1P to 1R, 2P to 2R, and 1A to 1F were foamed after the meters were installed. Units 2B to 2F and 1A to 1F had 1-1/4 inches of foam specified with actual thickness varying from 2 to 3 inches. Units 1P to 1R and 2P to 2R had 3 inches of PUF specified with actual thicknesses varying from 4 to 6 inches. The two different thicknesses of foam were specified to determine the optimum foam thickness for maximum energy conservation.

Electrical consumption data were analyzed in the following manner. When energy consumption exceeded 990 kW-hr/month, it was assumed that air conditioning was used regularly. The basis for this assumption was a marked jump in energy consumption from 700-800 kW-hr/month to 990 kW-hr/month and over. In all of the data collected and analyzed, there were only four or five instances that any one unit exhibited energy consumption between 800 and 990 kW-hr/month.

The housing units were not occupied continuously. Some units were occupied only for a fraction of the time that the meters were monitored. The electrical data were included only when the units were occupied. In addition, the data are included in the averages only when the usage exceeded 990 kW-hr/month as noted above.

A study of the data in Appendix B and in Table 5 shows that the energy consumption data for the two sets of units that were metered before foaming were fairly similar, 2,765 and 2,695 kW-hr/month. Since the monthly electrical consumption on these two groups of units was so similar, it seems appropriate to average these and use this average as the the energy consumption before foaming for the group of units that were metered after foaming. In this manner all three groups of units can be compared on a before and after foaming basis.

In order to simplify the discussion, the unit groupings - 5, 6, and 6 units - are listed as groups A, B, and C. The A units include system numbers 2B to 2F; the B units system numbers 1P to 1R, and 2P to 2R; and the C units system numbers 1A to 1F. Table 5 shows that energy consumption for unit groups A (2 to 3 inches of PUF) and B (4 to 6 inches of PUF) decreased by 13 and 12%, respectively, after the roofs were foamed. Group C units with 2 to 3 inches of foam, actually consumed 6% more energy after the roofs were foamed.

The reason for this increased energy consumption can be attributed to any of several different causes. Perhaps one of the most likely causes is the fact that the electrical consumption data were collected during the 8 to 9 months of cooler fall, winter, and spring weather when air conditioners were not operating. Had the "before" data been collected during the summer months and over at least a 2-year period, we believe that the results would have shown a reduction in electrical consumption rather than an increase.

Other causes include the fact that over the 2- to 2-1/2-year period that the data were collected, more than one family often lived in each of the units. This resulted in different living habits, different appliances, different numbers of window air conditioners, and, hence, different electrical energy consumption. Finally the tightness of the units is important. With the roof foamed, other sources of energy loss must be investigated. The units had jalousie windows that permitted a moderate degree of air infiltration and resultant energy loss.

When all of the above are considered, it is not surprising that the group C units increased their energy consumption after the roofs were foamed. Similarly, it is not surprising that the energy consumption in groups A and B decreased only 12 to 13 % after foaming, even though we believed that a considerable higher reduction would be realized. When groups A and B are compared to each other, 2 to 3 inches of foam versus 4 to 6 inches, there was little if any difference in energy consumption. This suggests that in such a case, 3 inches of foam is the optimum for electrical energy conservation with these particular units.

Cape Hatteras, N.C., Roofing

The performance of the PUF EERRS on the Galley at Cape Hatteras was determined periodically by noting and photographing any defects or deterioration of the roof system. Inspections were conducted after the roof had weathered for 1, 2 and 4.5 years. Results of the inspections are given in Table 6. After 1 year of exposure, the roof system was performing well and was rated VG to E (see description of rating system). The foam was well bonded to the edge, but there were a few small blisters between the lifts of foam (Figure 32).

After 2 years of weathering, the foam was still well bonded to the foam stop and no separation was noted anywhere around the perimeter of the building. There was blistering, mostly on the westerly half of the roof, and some of the blisters were as large as 8 inches in diameter. Some of the larger blisters exhibited an alligator pattern in the coating. The overall performance of the roof had diminished and was rated as VG to G.

After the 4.5 years of exposure, the Galley roof was divided in two for rating purposes because there was such a distinct difference in performance between the two halves of the roof. The westerly half had one small section along the perimeter where the foam was pulling loose from the edge where repairs had not been made, i.e., the foam and membrane had not been cut out and refoamed with 5 lb/ft^3 density foam. In addition, the amount and size of blisters had increased. There were at least 100 blisters ranging from 3 to 12 inches in diameter. Some of the blisters again exhibited an alligator pattern in the coating while others exhibited cracking of the coating and foam. None of the blisters had ruptured, and they again appeared to be between the lifts of foam. The westerly half of the roof was rated F to G in spite of the blistering because the roof was not leaking.

The easterly half of the roof was still performing well and was rated VG. Only one small blister was seen and there was no evidence of cracking foam around the edge. No other form of roof deterioration was observed.

There appears to be several reasons why one half of the roof performed much better than the other half. The easterly half was applied first by one of the contractors. While there were problems with cracking of the foam around the edge of the roof on the easterly half, this was repaired and caused no additional problems. Although the weather was far from optimum, the easterly half apparently was applied during better weather than the westerly half.

As noted earlier, the westerly half of the roof was open during an unexpected rainfall which soaked the gypsum concrete fill. The SAM was applied before the concrete fill was dry, and this probably accounted for more edge cracking problems in this area because the SAM did not adhere well to the damp concrete fill. The moisture present may also have contributed to the blistering problem. Finally, the application was made at a different time by a different applicator. It appears that some of the lifts of foam were applied over previous lifts that were not completely dry which would also account for heavy blistering. Polyurethane foam must be applied on a dry substrate; otherwise, bonding of the foam is diminished.

The cracking foam around the edges was basically caused by the SAM shrinking and pulling back from the edge. Although the SAM was bonded to the foam stop, its shrinkage still caused the foam to pull away from the foam stop and crack. This problem could have been prevented by mechanically fastening the membrane through the foam stop to the wooden nailer underneath.

FINDINGS AND CONCLUSIONS

Naval Station, Roosevelt Roads, P.R.

1. A 23-mil DFT vapor impermeable coating system (a catalyzed butyl/hypalon, System 5) performed very well and provided very good protection to the sprayed foam for at least 5 years with little or no maintenance.

2. The two vapor permeable coating systems included in the experiment (System 1 - acrylic, and System 2 - silicone) performed only moderately well for the 5-year exposure period. While the acrylic-coated PUF system performed slightly better than the silicone-coated PUF, neither of these performed as well as the butyl/hypalon coated system, System 5. Initial considerations suggest that the impermeable coating systems perform somewhat better than vapor permeable systems in this hot, humid environment. While the coating permeability probably has some affect on system performance, the thickness of the permeable coating systems averaged only about half of the specified coating thickness. We believe that this aspect is more important than the permeability of the coatings.

3. The urethane/hypalon and the hydrocarbon-modified urethane coatings, Systems 3 and 4, respectively, were also only half to two-thirds the specified coating DFT. The lack of coating thickness was again reflected in the systems' performance where Systems 3 and 4 were rated G to F, and P, respectively. System 3 provided the same degree of performance as the thicker silicone system. A similar urethane system (21 mils DFT) performed well in the NRC, Clifton tests. System 4 had the poorest performance of the five coating systems tested, which reinforces results obtained with this system in the NRC Clifton tests.

4. A minimum coating thickness is necessary for optimum PUF system performance. Results strongly support previous work at NCEL suggesting that the minimum DFT should be 30 mils.

5. Mineral roofing granules in the topcoat improved the systems' performance when applied over base coats of sufficient thickness. Fungicidal granules provided better weathering performance than regular granules in hot, humid environments.

6. TV antennas placed on any type of roof system can damage the system. This is particularly true on PUF roofs where the antenna masts were "walked" across the roof.

7. Featheredging the foam inside the edge of the roof is not an acceptable method of roof edge termination. The foam should be applied at full thickness to the edge of the roof or into a foam stop either at the edge of the roof or back at the exterior wall line.

8. No difference in performance was noted either between the three different foams or the same foam applied at the two different thicknesses.

9. For housing units with jalousie windows, optimum energy conservation is obtained with 1-1/2 to 3 inches of foam.

Naval Facility, Cape Hatteras, N.C.

1. A 25- to 30-mil DFT acrylic coated foam roof with mineral granules performed very well for at least 5 years without maintenance when properly applied.

2. When a modified bitumen membrane is applied underneath a sprayed PUF roof, mechanically fasten the membrane around the perimeter of the roof to prevent it from pulling the foam away from the foam stop. If the modified bitumen membrane is self-adhering, the roof substrate must be free of moisture to assure good adhesion.

RECOMMENDATIONS

1. The minimum DFT for any elastomeric coating system for foam should be at least 30 mils. Mineral roofing granules should be embedded in the topcoat of silicone and acrylic coating systems to improve performance. Fungicidal granules should be used in hot, humid environments.

2. Water-based, elastomeric coatings such as the acrylic coatings tested should not be used in hot, humid environments where they may not cure properly. Vapor permeable coatings should not be used on roofs with less than 1/2-in./ft slope because ponding water can be a problem.

3. For maximum energy conservation, when using air conditioners in hot, humid environments, air infiltration should be minimized by tightening the structure and replacing jalousie windows with a closed window. Two to 3 inches of foam should be used to provide maximum energy conservation in semitropical environments.

4. Foam should be applied into foam stops rather than featheredged around the perimeter of a roof. Foam in the foam stops and at flashings around penetrations in the roof should be coated with two additional coats of elastomeric coating or an application of a compatible caulking material before the topcoat is applied.

5. TV antennas should not be installed on PUF roofs but mounted on poles driven into the ground and attached to the roof's edge.

6. Trees and other foliage, which grow rapidly over roof decks in tropical or semitropical environments, should be trimmed periodically and all leaves and other debris removed to prolong the roof's life.

7. An annual inspection should be performed to identify and develop maintenance programs and repair requirements for each roof. Minor punctures and other defects should be corrected during the inspection by simply patching them with a compatible caulking material as the inspection progresses. Larger areas should be repaired, maintained, or refurbished as recommended in Reference 5.

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REFERENCES

1. Civil Engineering Laboratory. Technical Note N-1450 Experimental polyurethane foam roof systems, by J.R. Keeton, R.L. Alumbaugh, and E.F. Humm. Port Hueneme, Calif., Aug 1976.

2. Naval Civil Engineering Laboratory. Technical Note N-1656: Experimental poly-urethane foam roof systems - II, by R.L. Alumbaugh, J.R. Keeton, and E.F. Humm. Port Hueneme, Calif., Jan 1983.

3. Civil Engineering Laboratory. Technical Note N-1496: Investigation of spray-applied polyurethane foam roofing systems - I, by R.L. Alumbaugh and J.R. Keeton. Port Hueneme, Calif., Jul 1977.

4. Naval Civil Engineering Laboratory. Technical Note N-1643: Thermal conductivity of weathered polyurethane foam roofing, by D.A. Zarate and R.L. Alumbaugh. Port Hueneme, Calif., Sep 1982.

5. ___________. Technical Note N-1691: Preliminary guidelines for maintenance of polyurethane foam (PUF) roofing systems, by R.L. Alumbaugh, S.R. Conklin, and D.A. Zarate. Port Hueneme, Calif., Mar 1984.

6. ___________. Technical Note N-1683: Underwriters Laboratories fire tests of sprayed polyurethane foam applied directly to metal roof decks, by R.L. Alumbaugh and S.R. Conklin. Port Hueneme, Calif., Dec 1983.

7. Civil Engineering Laboratory. Purchase Order Report PO 79-MR-461: Principles of urethane foam roof application, by K.H. Coultrap. Tempe, Ariz., Coultrap Consulting Services, Inc., Jun 1980.

8. Naval Civil Engineering Laboratory. Techdata Sheet TDS 82-17: Sprayed polyurethane foam roofing systems. Port Hueneme, Calif., Oct 1982.

9. Civil Engineering Laboratory. Technical Note N-1600: Energy factors and temperature distribution in insulated built-up roofs, by J.R. Keeton and R.L. Alumbaugh. Port Hueneme, Calif., Feb 1981.

10. National Bureau of Standards. NBSIR 76-987: Effect of insulation on the surface temperature of roof membranes, by W.J. Rossiter and R.G. Mathey. Washington, D.C., Feb 1976.

Table 1. Description of Experimental Sprayed Polyurethane Foam Roofing Systems at Naval Station, Roosevelt Roads, Puerto Rico

Housing Unit No.	Polyurethane Foam[a]		Protective Coating System				Miscellaneous Information					
	Type[b]	Specified Thickness (in.)	Type[b] and System Description	No. of Coats	Total Dry Film Thickness (mils)		Granules	Date PUF System Installed	Date Electric Meters Installed	House Type	Roof Area (ft^2)	House Address
					Specified	Actual						
1A	A2	1-1/4	B1 - Acrylic Elastomer		30	0			17 Aug 1977	EN3	8,000	6 Ranger Road
1B			- White Base Coat	1		5	none	Jun 1978	17 Aug 1977	EN3		13 Ranger Road
1C			- White Topcoat	1		-			19 Aug 1977	EN3		20 Yorktown Circle
1D	A2	1-1/4	B1 - Acrylic Elastomer			20			22 Aug 1977	EN3	8,000	26 Yorktown Circle
1E			- White Base Coat	1		20	none	Jun 1978	19 Aug 1977	EN3		22 Coral Sea Drive
1F			- White Topcoat	1		-			16 Aug 1977	EN3		37 Coral Sea Drive
1G	A2	1-1/4	B1 - Acrylic Elastomer		30	-[c]				EN3	4,020	14 Ranger Road
1H			- White Base Coat	1		-	none	Jun 1978	none	EN3		4 Yorktown Circle
1I			- White Topcoat	1		-				EN4		6 Franklin Road
1J	A3	1-1/4	B1 - Acrylic Elastomer		30	25		Jun 1978		EN4	4,040	16 Yorktown Circle
1K			- White Base Coat	1		7	none	Jun 1978	none	EN4		56 Yorktown Circle
1L			- White Topcoat	1		7		May 1978		EN4		11 Franklin Road
1M	A2	1-1/4	B1 - Acrylic Elastomer		30	15				EN3	3,700	9 Ranger Road
1N			- White Base Coat	1		-	regular	Jun 1978	none	EN2		3 Yorktown Circle
1O			- White Topcoat	1		6				EN3		7 Franklin Road
1P	A2	3	B1 - Acrylic Elastomer		30	5			19 Oct 1977	EN3	4,020	18 Intrepid Drive
1Q			- White Base Coat	1		-	fungicidal	Jun 1978	15 Oct 1977	EN4		22 Hornet Road
1R			- White Topcoat	1		15			19 Oct 1977	EN3		6 Yorktown Circle
1S	A2	1-1/4	B1 - Acrylic Elastomer		30	20		Jun 1979		EN3	4,020	15 Yorktown Circle
1T			- White Base Coat	1		-	fungicidal	Jun 1978	none	EN4		14 Franklin Road
1U			- White Topcoat	1		-		Jun 1978		EN3		21 Coral Sea Drive

continued

Table 1. Continued

Housing Unit No.	Polyurethane Foam[a] Type[b]	Polyurethane Foam[a] Specified Thickness (in.)	Protective Coating System: Type[b] and System Description	Protective Coating System: No. of Coats	Total Dry Film Thickness (mils): Specified	Total Dry Film Thickness (mils): Actual	Miscellaneous Information: Granules	Date PUF System Installed	Date Electric Meters Installed	House Type	Roof Area (ft^2)	House Address
2A	A1	1-1/4	B2 - Moisture-Curing Silicone		15	-[c]			6 Oct 1977	-	-	10 Hornet Road
2B			- Light Gray Base Coat	1		13	none	Jun 1978	6 Oct 1977	-		70 Lexington Drive
2C			- White Topcoat	1		-			17 Oct 1977	-		8 Hancock Circle
2D	A3	1-1/4	B2 - Moisture-Curing Silicone		15	-[c]			20 Oct 1977	-	-	7 Intrepid Drive
2E			- Light Gray Base Coat	1		-	none	Jun 1978	18 Oct 1977	-		2 Ranger Road
2F			- White Topcoat	1		-			19 Oct 1978	-		3 Anzio Lane
2G	A2	1-1/4	B2 - Moisture-Curing Silicone		15	4				EN4	-	17 Ranger Road
2H			- Light Gray Base Coat	1		-	regular (dark)	Jun 1978	none	EN3		16 Hornet Road
2I			- White Topcoat	1		-				EN4		50 Yorktown Circle
2J	A2	1-1/4	B2 - Moisture-Curing Silicone		22	-				EN3	-	18 Ranger Road
2K			- Light Gray Base Coat	1		15	none	Jun 1978	none	EN4		17 Hornet Road
2L			- White Top Coat	1		12				EN4		39 Yorktown Circle
2M	A3	1-1/4	B2 - Moisture-Curing Silicone		22	12				EN3	4,040	16 Ranger Road
2N			- Light Gray Base Coat	1		-	none	Jun 1978	none	EN4		22 Yorktown Circle
2O			- White Topcoat	1		-				EN3		30 Yorktown Circle
2P	A2	3	B2 - Moisture-Curing Silicone		22	-		Jun 1978	18 Oct 1977	EN3	4,000	1 Ranger Road
2Q			- Light Gray Base Coat	1		-	fungicidal	Jun 1978	17 Oct 1977	EN3		1 Yorktown Circle
2R			- White Topcoat	1		15		Jul 1978	6 Oct 1977	EN3		15 Hornet Road
2S	A2	1-1/4	B2 - Moisture-Curing Silicone		22	-				EN3	4,000	2 Randolph Road
2T			- Light Gray Base Coat	1		-	fungicidal	Jun 1978	none	EN3		19 Yorktown Circle
2U			- White Topcoat	1		20				EN3		29 Yorktown Circle

continued

Table 1. Continued

Housing Unit No.	Polyurethane Foam[a]		Protective Coating System				Miscellaneous Information					
	Type[b]	Specified Thickness (in.)	Type[b] and System Description	No. of Coats	Total Dry Film Thickness (mils) Specified	Actual	Granules	Date PUF System Installed	Date Electric Meters Installed	House Type	Roof Area (ft^2)	House Address
3A	A2	1-1/4	B3 - Catalyzed Urethane		20	8		May 1979		EN4	4,020	18 Hornet Road
3B			- Aluminum, Catalyzed Urethane Base Coat	1	20	25	none	Jun 1978	none	EN3		42 Yorktown Circle
3C			- White Hypalon Topcoat	1	20	10		Jun 1978		EN3		54 Yorktown Circle
4A	A2	1-1/4	B4 - Catalyzed Modified Urethane		48	30-35		May 1978		EN3	4,000	21 Hornet Road
4B			- Black, Catalyzed Modified Urethane Base Coat	1		8-20	none	Jun 1978	none	EN3	4,000	31 Yorktown Circle
4C			- Aluminum, Catalyzed Urethane Topcoat	1		-		Jun 1978		EN3		5 Franklin Road
5A	A2	1-1/4	B5 - Catalyzed Butyl-Hypalon		23	20-40		Jun 1978		EN3	4,020	47 Yorktown Circle
5B			- Tan, Catalyzed Butyl Base Coat	1		18	none	May 1978	none	EN3		19 Coral Sea Drive
5C			- White Hypalon Topcoat	1				May 1978		EN3		31 Coral Sea Drive

[a]All PUF 3 pcf density.

[b]See Appendix A for description of foam and coating designations.

[c]Dry film thickness not determined.

Table 2. Experimental PUF Roof Systems at Naval Station, Roosevelt Roads, P.R.

System Description[a]	Thickness (mils)		Foams Used	No. of Units	Units With Granules	Units With Meters
	Specified	Measured				
1. Acrylic Elastomer	30	5-25 [13][b]	A, B	21	9	9
White Base Coat	15					
White Topcoat	15					
2a. Silicone Elastomer	15	4-13 [8]	A, B, C	9	3	6
Light Gray Base Coat	7.5					
White Topcoat	7.5					
2b. Silcone Elastomer	22	12-20 [15]	A, B	12	6	3
Light Gray Base Coat	11					
White Topcoat	11					
3. Catalyzed Urethane/Hypalon	20	8-25 [14]	A	3	0	0
Aluminum Urethane Base Coat	15					
White Hypalon Topcoat	5					
4. Catalyzed Modified Urethane	48	8-35 [24]	A	3	0	0
Blk. Modified Urethane Base Coat	40					
Al. Modified Urethane Topcoat	8					
5. Catalyzed Butyl/Hypalon	23	18-40 [24]	A	3	0	0
Tan Butyl Base Coat	19					
White Hypalon Topcoat	4					

[a] All are two-coat systems.

[b] Average thickness of samples taken in brackets.

Table 3. Performance Ratings for Coated PUF Roofing Systems at Naval Station, Roosevelt Roads, Puerto Rico

Housing Unit No.	Protective Coating System	Coating Thickness (mils)	Granules	Polyurethane Foam		Performance Ratings After[a]		Remarks
				Type	Specified Thickness (in.)	1 Yr	5 Yr	
1A	Acrylic Elastomer	30 [0][b]	none	A2	1-1/4	F	P	Mildew growth. Some blistering and cracking of coating. Erosion by foliage.
1B		[5]				G	P	Pinholes in coating. Mildew growth. Some blistering and cracking of coating. Erosion by foliage. Three trees growing in PUF.
1C						VG	P	Some cracking and blistering of coating.
1D	Acrylic Elastomer	30 [20]	none	A2	1-1/4	VG	F	Some blistering and cracking of coating. Erosion by foliage.
1E		[20]				VG	VG	Erosion by foliage. Some birdpecking.
1F						VG	VG	Mildew growth.
1G	Acrylic Elastomer	30	none	A2	1-1/4	c	G	
1H						E	G	Some blistering and cracking.
1I						c	F	Mildew growth. Some blistering and cracking.
1J	Acrylic Elastomer	30 [25]	none	A3	1-1/4	E	E	Mildew growth. Erosion by foliage. Flowers and trees growing in PUF.
1K		[7]				E	E	Trees growing in PUF.
1L		[7]				G-F	F	Mildew growth.

continued

Table 3. Continued

Housing Unit No.	Protective Coating System	Coating Thickness (mils)	Granules	Polyurethane Foam		Performance Ratings After[a]		Remarks
				Type	Specified Thickness (in.)	1 Yr	5 Yr	
1M	Acrylic Elastomer	30 [15]	regular	A2	1-1/4	c	F	
1N						VG	VG	Some blistering and cracking. Erosion by foliage.
1O		[6]				c	F	
1P	Acrylic Elastomer	30 [5]	fungicidal	A2	3	VG	G	Some blistering and cracking.
1Q						VG	G	Coating patched with asphalt.
1R		[15]				E	VG	
1S	Acrylic Elastomer	30 [20]	fungicidal	A2	1-1/4	c	G	Erosion by Foliage.
1T						c	VG	
1U						c	E	
2A	Moisture-Curing Silicone	15	none	A1	1-1/4	G	F	Pinholes, blistering, and cracking of coating. Birdpecking. Mildew growth.
2B		[13]				VG	P	Pinholes, blistering, and cracking of coating. Birdpecking. Erosion by foliage.
2C						F	F	Coating patched with asphalt.

continued

Table 3. Continued

Housing Unit No.	Protective Coating System	Coating Thickness (mils)	Granules	Polyurethane Foam		Performance Ratings After[a]		Remarks
				Type	Specified Thickness (in.)	1 Yr	5 Yr	
2D	Moisture-Curing Silicone	15	none	A3	1-1/4	VG	VG	Some blistering and cracking of coating. Erosion by tree foliage.
2E						c	G	Some pinholes, blistering, and cracking of coating. Trees growing in PUF. Erosion by tree foliage.
2F						G	F	Some blistering and cracking of coating. Birdpecking. Erosion by tree foliage.
2G	Moisture-Curing Silicone	15 [4]	regular	A2	1-1/4	c	F	Some blistering and cracking of coating. Erosion by tree foliage. Birdpecking.
2H						c	F	Some blistering and cracking of coating. Birdpecking.
2I						VG	P	Some blistering and cracking of coating. Birdpecking.
2J	Moisture-Curing Silicone	22	none	A2	1-1/4	E	VG	Some blistering and cracking of coating.
2K		[15]				c	G	Banyan tree growing in PUF full length of house.
2L		[12]				c	F	Some blistering and cracking of coating.

continued

Table 3. Continued

Housing Unit No.	Protective Coating System	Coating Thickness (mils)	Granules	Polyurethane Foam		Performance Ratings After[a]		Remarks
				Type	Specified Thickness (in.)	1 Yr	5 Yr	
2M	Moisture-Curing Silicone	22 [12]	none	A3	1-1/4	c	VG	
2N						VG	VG	
2O						E	VG	
2P	Moisture-Curing Silicone	22	fungicidal	A2	3	VG	G	Some blistering and cracking of coating. Erosion by tree foliage.
2Q		22				G	G	Erosion by tree foliage. Trees growing in PUF.
2R		22 [15]				G	P	Some blistering and cracking of coating. Erosion by tree foliage.
2S	Moisture-Curing Silicone	22	fungicidal	A2	1-1/4	c	G	Erosion by tree foliage.
2T		22				G	F	Some blistering and cracking of coating.
2U		22 [20]				G	G	
3A	Catalyzed Urethane	20 [8]	none	A2	1-1/4	c	F	Erosion by tree foliage.
3B		20 [25]				E	G	Some cracking and puncturing of coating.
3C		20 [10]				VG	F	Mildew growth.

continued

Table 3. Continued

Housing Unit No.	Protective Coating System	Coating Thickness (mils)	Granules	Polyurethane Foam		Performance Ratings After[a]		Remarks
				Type	Specified Thickness (in.)	1 Yr	5 Yr	
4A	Catalyzed Modified Urethane	48 [30-35]	none	A2	1-1/4	c	P	Coating exhibits cracking, holes and punctures, causing severe coating deterioration and failure.
4B		48 [8-20]				c	P	Coating exhibits cracking, holes and punctures, causing severe coating deterioration and failure.
4C		48				F	P	Coating exhibits cracking, holes and punctures, causing severe coating deterioration and failure.
5A	Catalyzed Butyl-Hypalon	23 [20-40]	none	A2	1-1/4	E	G	Topcoat chalks heavily, but no severe deterioration.
5B		23 [18]				c	E	Topcoat chalks heavily, but no severe deterioration.
5C		23				c	VG	Topcoat chalks heavily, but no severe deterioration.

[a] Ratings: E = Excellent; VG = Very Good; G = Good; F = Fair; P = Poor.

[b] Numbers in brackets are actual thicknesses measured.

[c] System not rated.

Table 4. Performance Ratings of PUF Roofing Systems after 5 Years at Naval Station, Roosevelt Roads, P.R.

System Description	Thickness (mils)	No. of Units With Performance Rating[a] of					Overall Ratings		
		E	VG	G	F	P	All	With Granules	Without Granules
1. Acrylic	30 [13][b]	3	5	5	5	3	G	G-VG	G-F
2. Silicone	15 [8]	-	1	1	5	2	F	F-P	F-P
	22 [15]	-	4	5	2	1	G-F	G-F	F-G
3. Urethane/Hypalon	20 [14]	-	-	1	2	0	G-F	-	G-F
4. Modified Urethane	48 [24]	-	-	-	-	3	P	-	P
5. Butyl/Hypalon	23 [24]	1	1	1	-	-	VG	-	VG

[a]E = Excellent; VG = Very Good; G = Good; F = Fair; P = Poor

[b]Average thickness of samples taken in brackets.

Table 5. Electrical Energy Savings After Foaming at Naval Station, Roosevelt Roads, P.R.

Unit Grouping	Foam Thickness (in.)	Average Monthly Electrical Consumption ≥ 990 kW-hr		Change (%)
		Before Foaming	After Foaming	
A (5 Units)	1-1/4	2,730[a]	2,377	-13
B (6 Units)	3	2,765	2,437	-12
C (6 Units)	1-1/4	2,694	2,854	+6

[a]Average of B and C values for consumption before foaming.

Table 6. Performance Ratings of PUF Roofing System on Galley at Naval Facility, Cape Hatteras, N.C.

[Self-adhering membrane, 2-1/4-in. of PUF (2.5 lb/ft^3), 25 mils of acrylic, and mineral roofing granules]

No. of Years	Performance Rating[a]	Remarks
1	VG-E	Few small blisters. Foam well adhered to edge flashing.
2	VG-G	Additional blistering. Coating alligatoring on top of blisters. No edge problem.
4.5	F-G	Westerly end - Up to 100 blisters. Top lift of PUF or foam membrane (3-in. diam to 12 in.). Small area PUF pulling loose from flashing.
4.5	VG	Easterly end - Only 1 blister. Foam bonded well around edge. System performing well.

[a]E = Excellent; VG = Very Good; G = Good; F = Fair; P = Poor.

Figure 1. Typical experimental house with low slope concrete roof deck. Note tropical foliage, which is often dense, and roof mounted TV antenna. Naval Station, Roosevelt Roads, P.R.

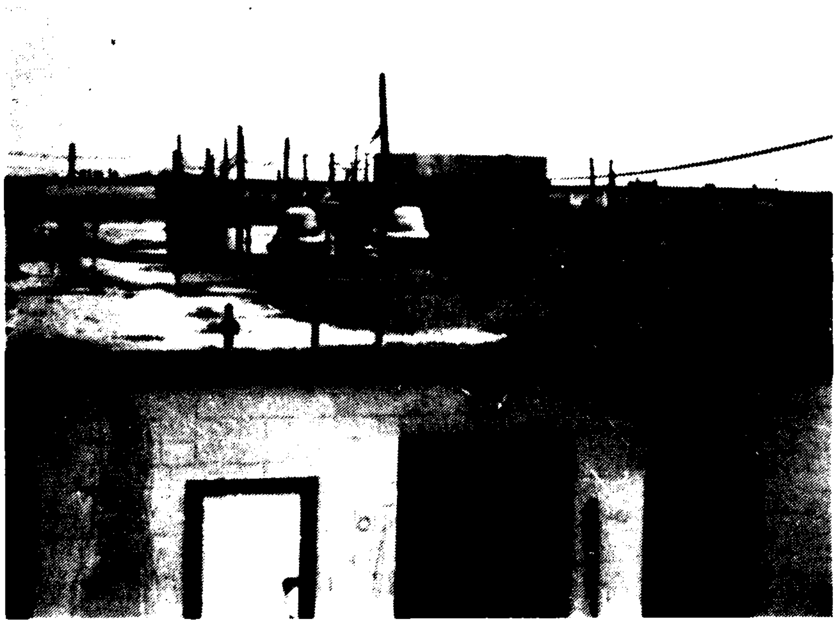

Figure 2. Overview of old BUR on Galley, Naval Facility, Cape Hatteras, N.C.

Figure 3. The self-adhering membrane (SAM) after application to the gypsum concrete fill of the roof of the Galley, Naval Facility, Cape Hatteras, N.C.

Figure 4. Workman remove PUF and SAM from damp area of Galley's roof where SAM did not adhere to gypsum concrete fill. Naval Facility, Cape Hatteras N.C.

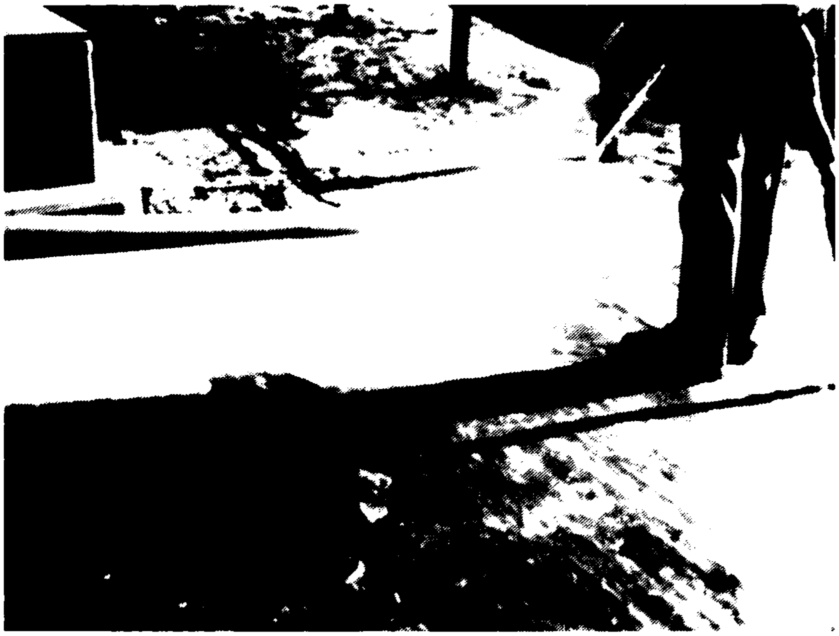

Figure 5. PUF being sprayed directly onto the SAM that adhered to the gypsum concrete fill of the Galley. Naval Facility, Cape Hatteras, N.C.

Figure 6. Applying gray acrylic elastomer base coat (coating B1) to PUF on the Galley's roof. Naval Facility, Cape Hatteras, N.C.

Figure 7. The SAM applied to gypsum concrete fill and edge flashing pulled away from flashing causing the foam to separate from the edge flashing. Galley, Naval Facility, Cape Hatteras, N.C.

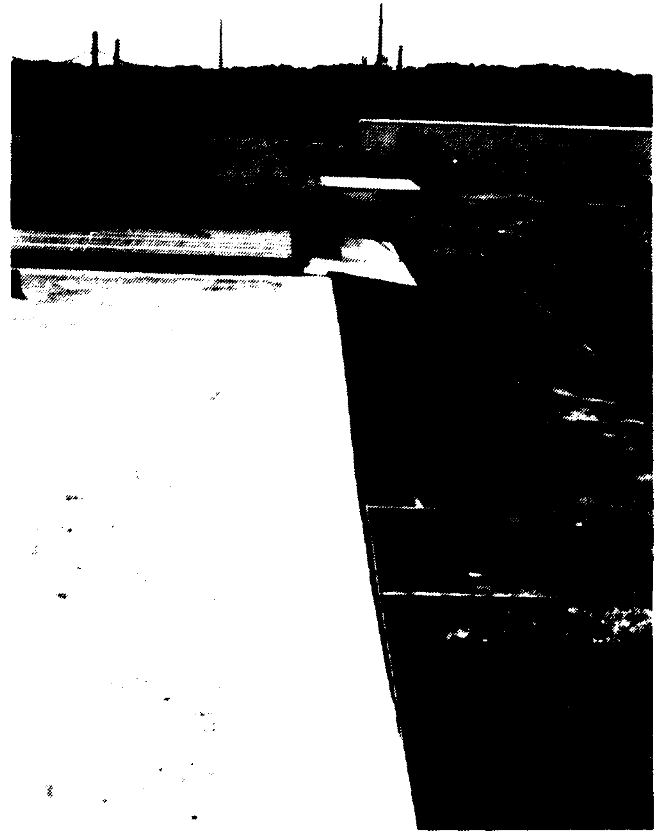

Figure 8. Contractor has cut out foam and SAM about 12 inches back from the edge flashing and refoamed and recoated the area. Galley, Naval Facility, Cape Hatteras, N.C.

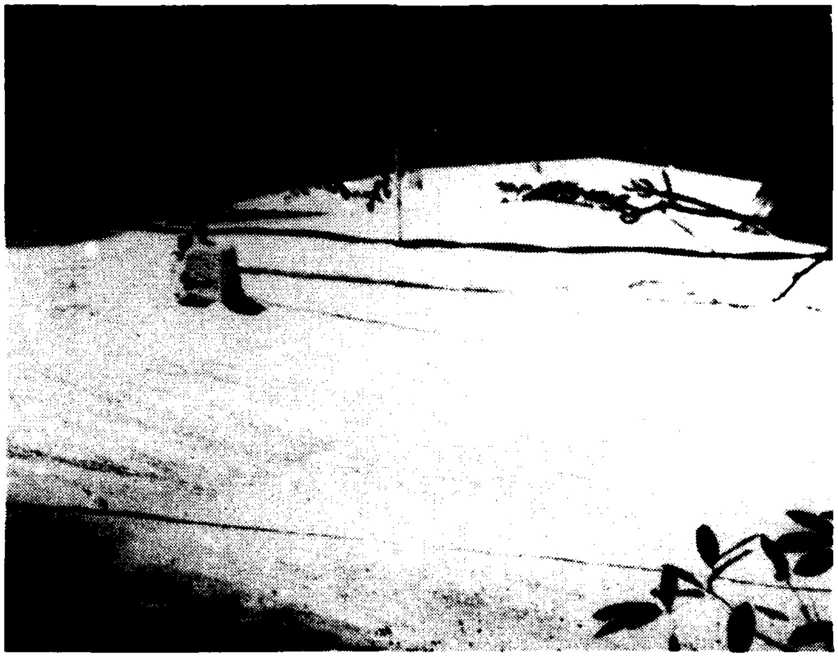

Figure 9. System 2 - Silicone without granules. Condition rated good except for damage from TV mast. Naval Station, Roosevelt Roads, P.R.

Figure 10. System 2 - Silicone without granules. Pattern of punctures indicates TV mast may have been "walked" across the roof while steadied with guy wires. Naval Station, Roosevelt Roads, P.R.

Figure 11. System 2 - Silicone with fungicidal granules. In good condition despite accumulation of leaves and tree limb erosion. Naval Station, Roosevelt Roads, P.R.

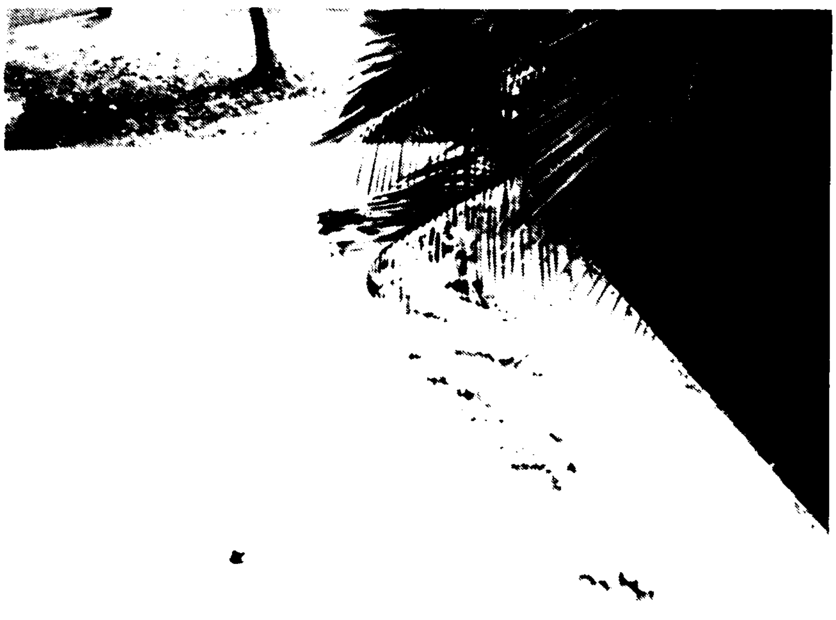

Figure 12. System 2 - Silicone with fungicidal granules. Typical palm tree erosion but minimal fungus or algae growth. Naval Station, Roosevelt Roads, P.R.

Figure 13. System 1 - Acrylic elastomer without granules. Severe accumulation of dead tree limbs and leaves; plants growing in punctures. Naval Station, Roosevelt Roads, P.R.

Figure 14. System 1 - Acrylic elastomer with regular granules. Dense accumulation of tree leaves and other debris. Tree roots growing in PUF are breaking it into pieces. Naval Station, Roosevelt Roads, P.R.

Figure 15. System 2 - Silicone with regular granules. Typical PUF flashings coated with heavy coat of silicone are in excellent condition. Naval Station, Roosevelt Roads, P.R.

Figure 16. System 2 - Silicone with regular granules. Poor performance due to coating being applied too thin. Note pedestal for incoming electrical service and loss of granules because of inadequate coating thickness and improper granule embedment. Naval Station, Roosevelt Roads, P.R.

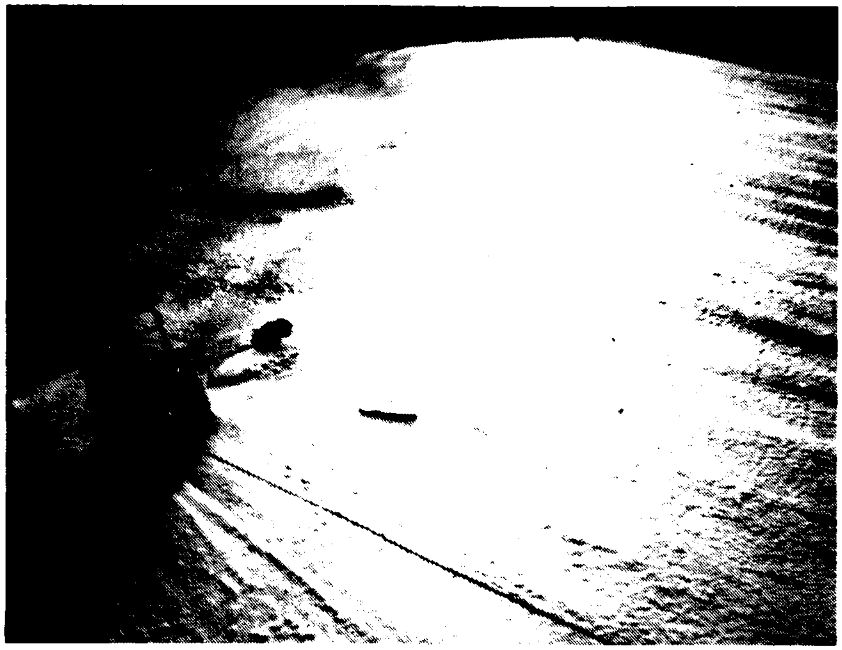

Figure 17. System 5 - Butyl/hypalon system without granules. Very good performance except for large puncture and some bleeding of the butyl base coat on left side (discoloration and streaking). Note pedestal for incoming phone service. Naval Station, Roosevelt Roads, P.R.

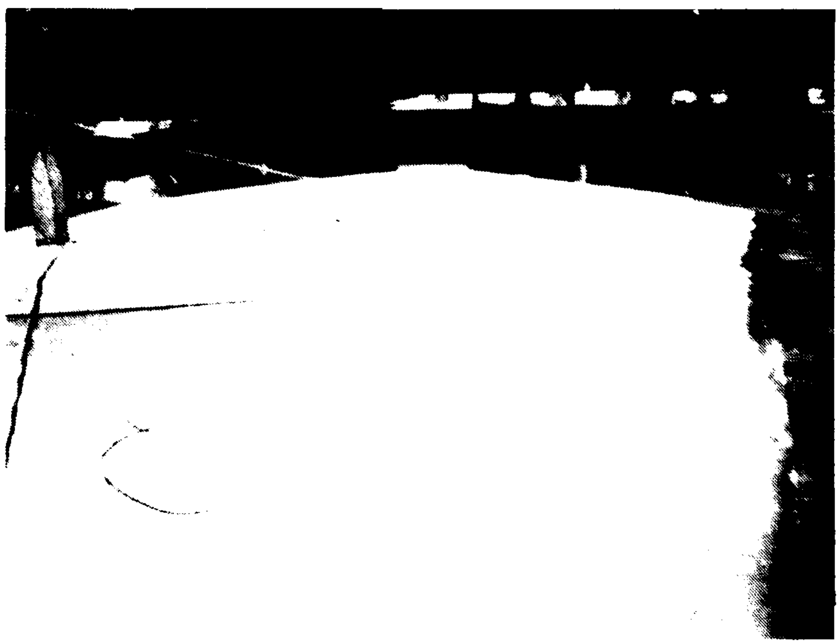

Figure 18. System 1 - Acrylic elastomer without granules. Performance rated good in spite of fungal stains all over roof particularly along edge of foam. Note electrical and telephone service wires laying on top of acrylic coating. Naval Station, Roosevelt Roads, P.R.

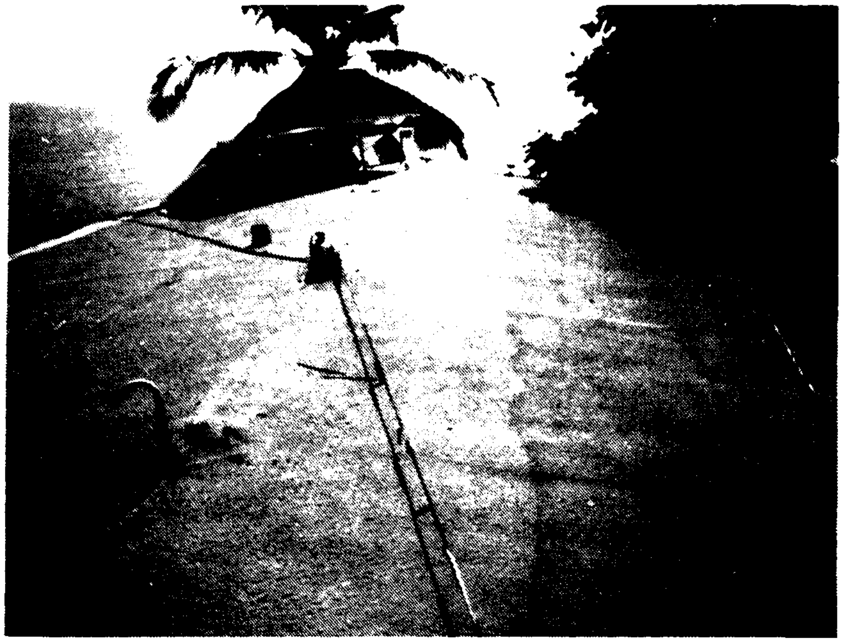

Figure 19. System 1 - Acrylic elastomer with fungicidal granules. Condition very good except for punctures near pipe. Note wires laying on or near coated surface. Naval Station, Roosevelt Roads, P.R.

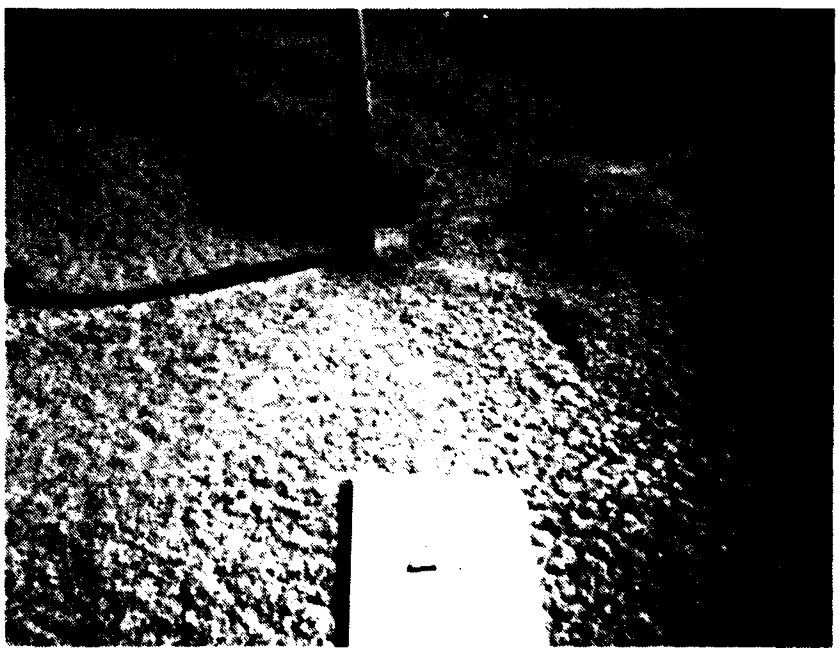

Figure 20. System 1 - Acrylic elastomer coating with fungicidal granules. Close-up of rough surface texture. There is no foam flashing around pipe and punctures in coating adjacent to pipe. Naval Station, Roosevelt Roads, P.R.

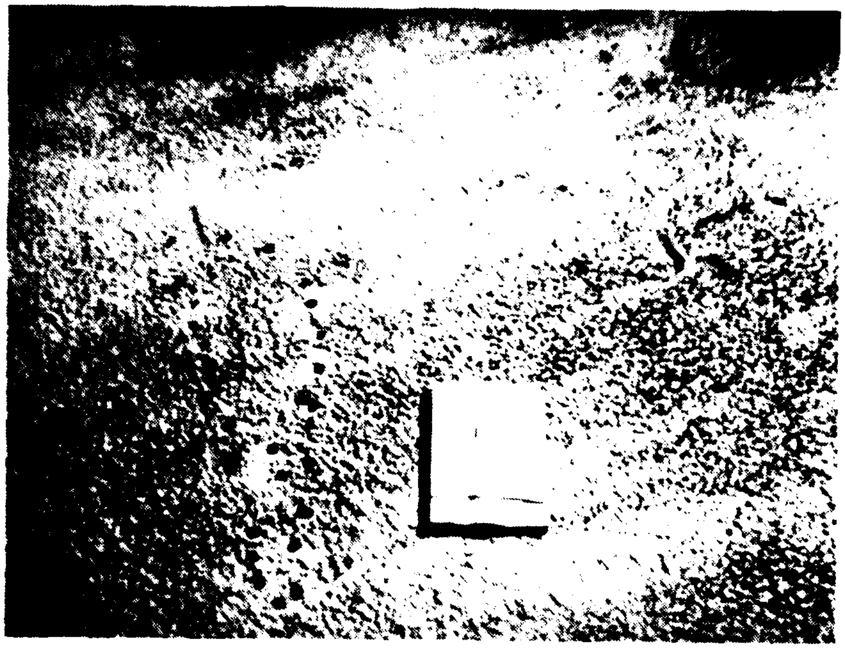

Figure 21. Close up of System 1 - Acrylic elastomer without granules. Note punctures caused by antenna masts, and very rough foam surface texture. Naval Station, Roosevelt Roads, P.R.

Figure 22. System 1 - Acrylic elastomer without granules. Additional punctures caused by antenna masts. Naval Station, Roosevelt Roads, P.R.

Figure 23. Severe fungal staining and deterioration of coating and foam along edge due to feather-edging of foam. Foam should terminate at edge of roof deck or in foam stop. Naval Station, Roosevelt Roads, P.R.

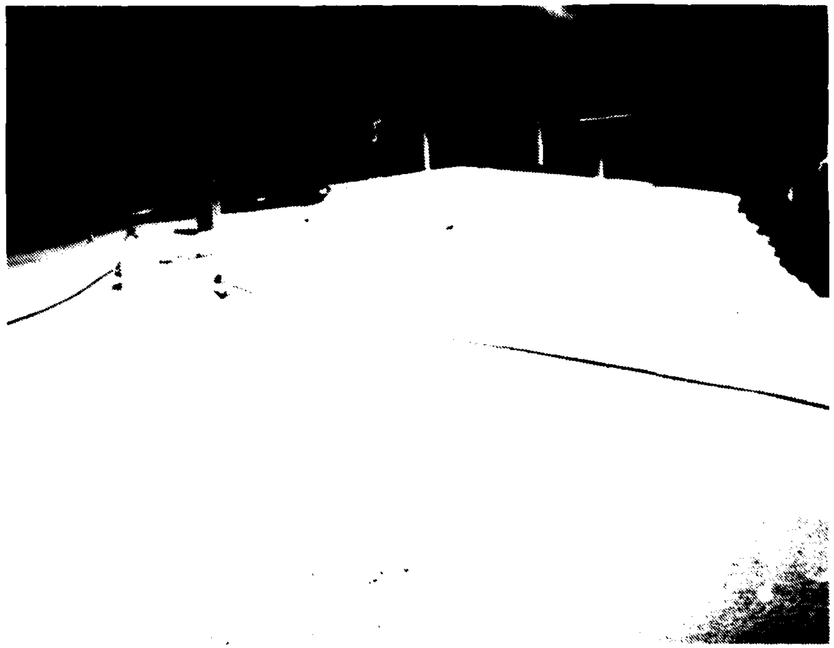

Figure 24. System 2 - Silicone without granules. System in very good condition except for deterioration along termination at edge of roof. Naval Station, Roosevelt Roads, P.R.

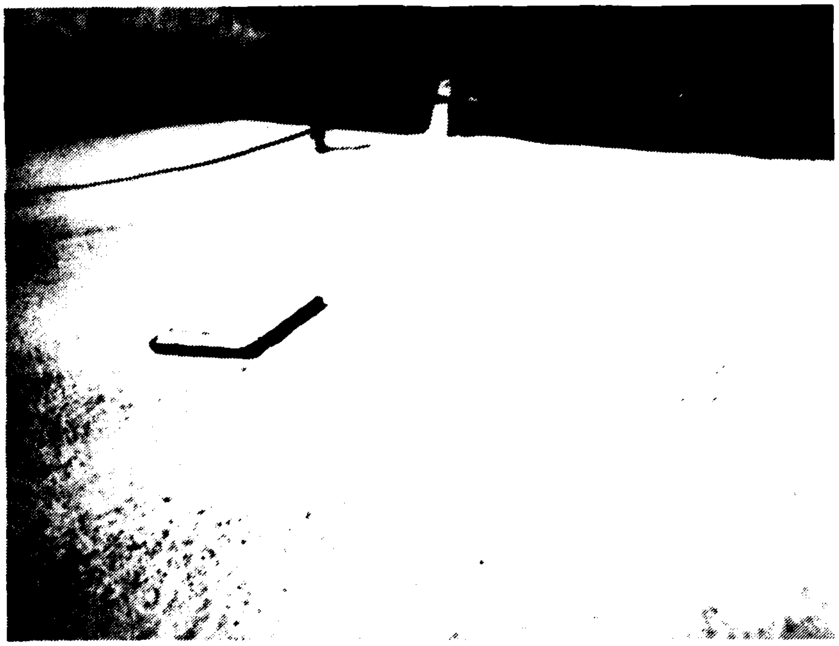

Figure 25. System 2 - Silicone without granules. System in very good condition. Naval Station, Roosevelt Roads, P.R.

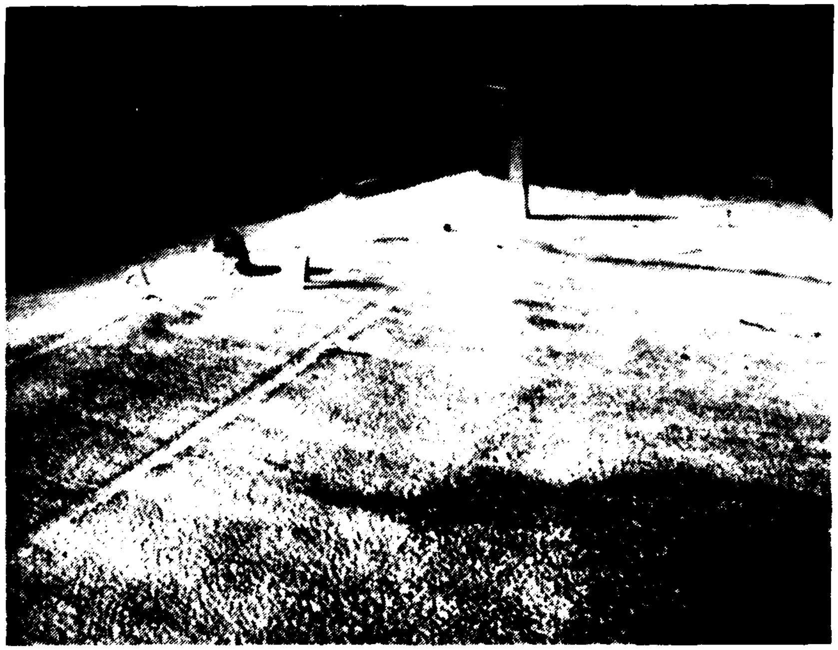

Figure 26. System 3 - Urethane/hypalon without granules in good condition. Fungus growth in valleys of rough surface texture gives roof a dark gray appearance. Naval Station, Roosevelt Roads, P.R.

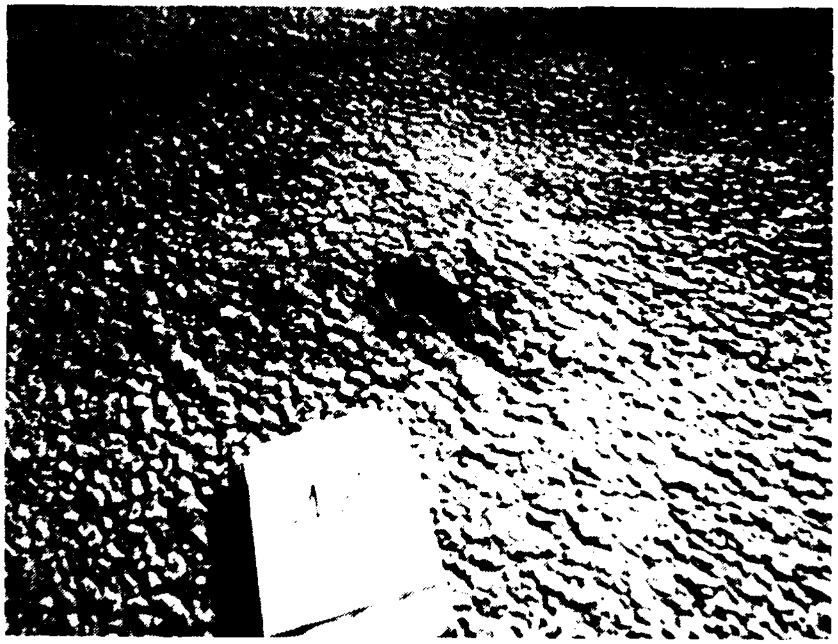

Figure 27. System 3 - Urethane/hypalon without granules. Close up of single puncture on roof. Fungus growth heavy in valleys of verge-of-popcorn surface texture. Naval Station, Roosevelt Roads, P.R.

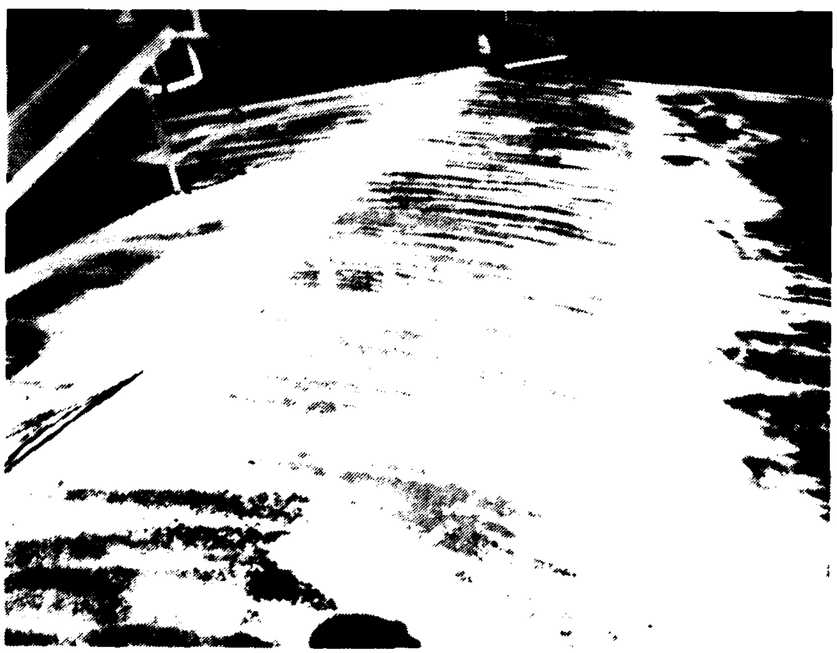

Figure 28. System 4 - Aluminum-pigmented, modified urethane without granules. Coating system has completely failed. PUF exposed to UV degradation for some time. Naval Station, Roosevelt Roads, P.R.

Figure 29. System 4 - Aluminum-pigmented, modified urethane without granules. Coating and PUF have been severely degraded. Note severely degraded areas of foam that hold water; still no leaks were reported. Naval Station, Roosevelt Roads, P.R.

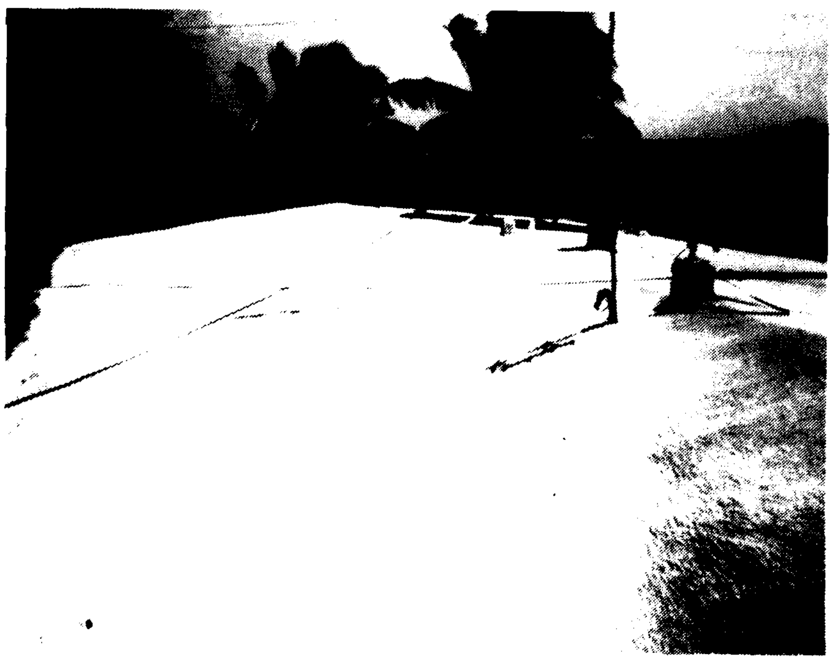

Figure 30. System 5 - Butyl/hypalon without granules rated excellent. Naval Station, Roosevelt Roads, P.R.

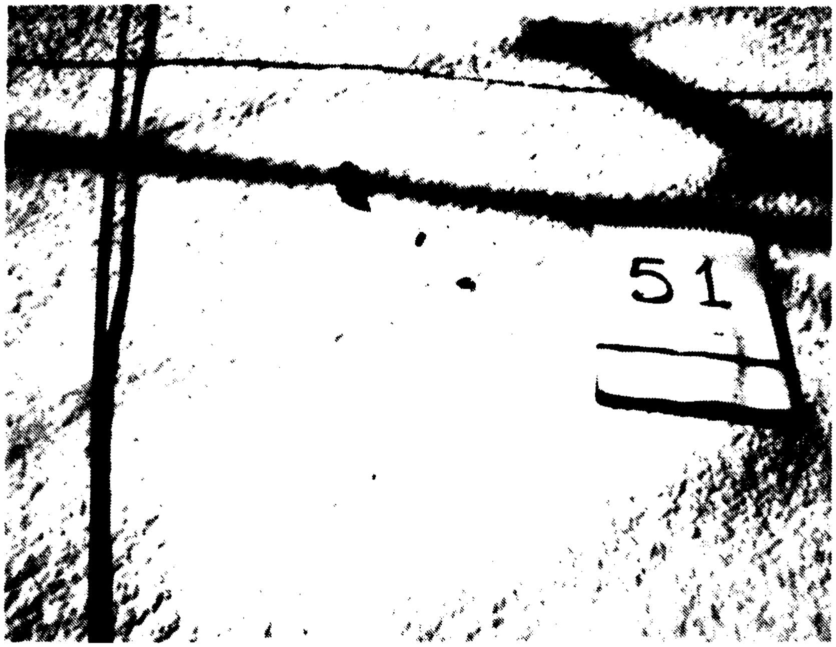

Figure 31. System 5 - Butyl/hypalon without granules in very good condition. Coating thickness complied with specification. Only one puncture was noted. Naval Station, Roosevelt Roads, P.R.

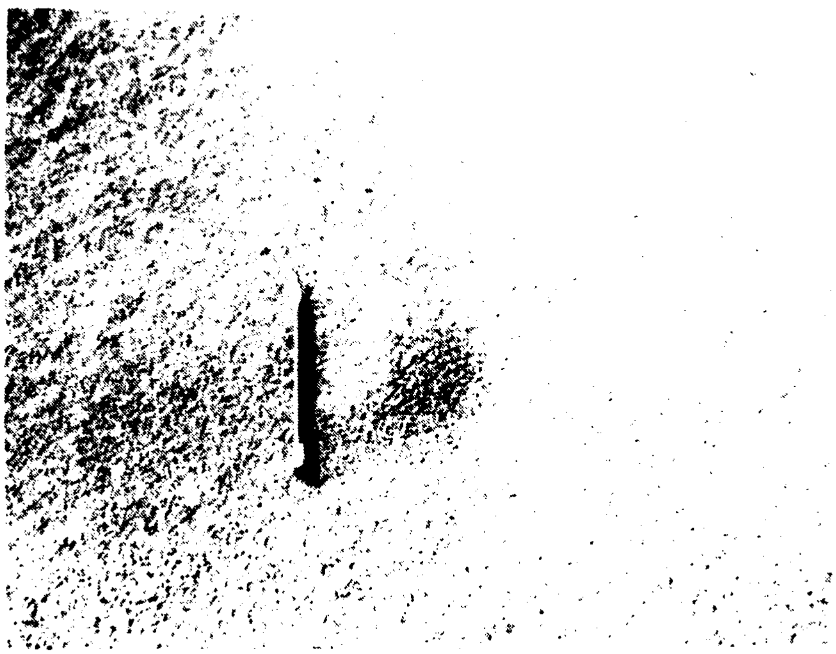

Figure 32. Acrylic elastomer coated foam roof on the Galley, Naval Facility, Cape Hatteras, N.C., showed mild blistering after 1 year and dense blistering on westerly half after 4.5 years.

Appendix A

EXPERIMENTAL POLYURETHANE FOAM (PUF) ROOFING SYSTEMS: MATERIAL AND SOURCES FOR NAVAL STATION, ROOSEVELT ROADS, P.R. AND NAVAL FACILITY, CAPE HATTERAS, N.C.

I. EXPERIMENTAL VARIABLES AND MATERIAL SOURCES

A. Polyurethane Foam (PUF) - 3 lb/cu ft density:

1. CPR Upjohn - CPR 485-3	CPR Division, The Upjohn Company 555 Alaska Avenue Torrance, CA 90503
2. CPR Upjohn - CPR 468-3	CPR Division, The Upjohn Company
3. Witco - SS 0125A/SS 0126B	Isocyanate Products Inc 900 Wilmington Road New Castle,DE 19720 (formerly Isocyanate Products Division, Witco Chemical)
4. CPR Upjohn - CPR 485-2.5	CPR Division, The Upjohn Company

B. Elastomeric Coating Systems:

1. Acrylic - Diathon	United Coatings 1130 East Sprague Ave Spokane, WA 99202
2. Silicone - 3 - 5000	Dow Corning Corp Midland, MI 48640
3. Urethane - Irathane 300 Hypalon - Irathane 157	Irathane Systems, Inc Industrial Park Hibbing, MN 55746
4. Modified Urethane Roof-Flex 145 Roof-Flex 155	Carboline 350 Industrial Ct. St Louis, MO 63144
5. Butyl - Elastron 858 Hypalon - Elasto-mir 35	United Coatings 1130 East Sprague Ave Spokane, WA 99202

C. Mineral Roofing Granules

1. Plain 2. Fungus and algae resistant	3-M Company St Paul, MN 55101

D. Self-Adhering Membrane (SAM)

1. Heavy Duty Bituthene	W.R. Grace & Co. Cambridge, MA II.

II. APPLICATION SPECIFICATIONS

A. Coating Systems

Coating System B1 - United Coatings Diathon

1. Apply Diathon in two coats at a rate of 1-1/2 gallons per 100 ft^2 for a wet film thickness of 25 mils.
2. Total dry film thickness should be 30 mils.
3. Dry base coat for a minimum of 18 to 24 hours, and longer if necessary, before applying topcoat.

Coating System B2 - Dow Corning Silicone 3-5000

1. Apply the base coat, 3-5000 gray and the topcoat, 3-5000 white, at a rate of 1 gallon per square for a wet film thickness of 10 to 11 mils, and a dry film thickness of 7.5 mils.
2. Total minimum dry film thickness shall be 15 mils.
3. For systems specified at 22 mils minimum dry film thickness, apply both coats at a rate of 1-1/2 gallons per 100 ft^2 for a nominal wet film thickness of 15 mils and a dry film thickness of 11 mils.
4. Cure base coat 6 to 24 hours before applying topcoat.

Coating System B3 - Irathane System Weather/Flex

1. Apply the base coat, Irathane 300 urethane elastomer, at a rate of 2 gallons per 100 ft^2 for a nominal wet film thickness of 30 mils and a dry film thickness of 15 mils.
2. Apply the topcoat, Irathane 157 hypalon, at a rate of 1 gallon per 100 ft^2 for a nominal wet film thickness of 20 mils and a nominal dry film thickness of 5 mils.
3. Total minimum dry film thickness shall be 20 mils.
4. Apply the topcoat as soon as base coat is dry. Topcoat must be applied within 24 hours, if not, a special conditioner is required before applying the topcoat.

Coating System B4 - Carboline Roof-Flex

1. Apply the base coat, Roof-Flex 145 (black), at a rate of 3 gallons per 100 ft^2 for a nominal wet film thickness of 41 mils and a minimum dry film thickness of 40 mils.

2. Apply the topcoat, Roof-Flex 155A (aluminum), at a rate of 1 gallon per 100 ft^2 for a nominal wet film thickness of 14 to 15 mils and a dry film thickness of 8 to 10 mils.

3. Total minimum dry film thickness for this system shall be 40 mils.

Coating System B5 - United Coatings Elastron 858/Elastro-mir 35

1. Apply base coat, Elastron 858 (tan butyl), at a rate not less than 2-1/2 gallons per 100 ft^2 for a nominal wet film thickness of 39 mils and a minimum dry film thickness of 19 mils.

2. Apply topcoat, Elastro-mir 35 (white hypalon) at a rate of 1 gallon per 100 ft^2 for a nominal wet film thickness of 12 mils and a dry film thickness of 4 mils.

3. Total minimum dry film thickness shall be 23 mils.

4. Cure base coat for 24 hours before applying topcoat.

B. Mineral Roofing Granules (white)

1. Apply granules with a sandblaster, modified to control pressure at 10 to 20 psi, at a rate of at least 50 lb/100 ft^2.

2. Apply granules into wet topcoat (the second coat) within 5 minutes.

3. Apply granules in a minimum of two passes at right angles. The finished granule system shall be uniform over the entire surface.

4. Permit no traffic on rooftop for 24 hours after granules have been applied.

Appendix B

TOTAL ELECTRICAL CONSUMPTION DATA
FOR
NAVAL STATION, ROOSEVELT ROADS, P.R.

Appendix B

TOTAL ELECTRICAL CONSUMPTION DATA FOR NAVAL STATION, ROOSEVELT ROADS, P.R.

No.	Date	No. of Days	Group A (1-1/4-in. Foam) (kW-hr/mo)					Group B (3-in. Foam) (kW-hr/mo)						Group C (1-1/4-in. Foam) (kW-hr/mo)					
			2B	2C	2D	2E	2F	1P	1Q	1R	2P	2Q	2R	1A	1B	1C	1D	1E	1F
1	11/16/77	12	1,052[e]	453[e]	99[a,b]	1,000[b]	82[a,b]	689	1,382	135[a]	976	1,389	2,177	559	1,062	916[c]	1,737	974[c]	464
2	11/28/77	30	2,330	3,709	261[a]	2,574	331[a]	1,615	2,927	270[a]	2,518	3,718	1,406	1,487	2,994	3,221	2,014	3,950	1,911
3	12/28/77	30	517[a]	3,069	387[a]	2,740	86[a]	2,332	2,072	172[a]	444	3,102	3,026	1,931	2,219	883	777	3,929	523
4	1/27/78	32	210[a]	1,496[a,d]	716	467[a]	175[a]	620	2,254	106[a]	1,310	3,527	3,029	1,043	3,293	402	2,027	4,183	213[a]
5	2/28/78	28	208[a]	167	662	65[a]	181[a]	1,404	2,017	116[a]	449	3,397	2,603	839	3,185	700	1,792	3,664	218[a]
6	3/28/78	31	1,913[a]	2,261	819	108[a]	411[a]	1,662	2,327	1,793	500	3,650	3,582	1,266	3,159	1,301	2,159	4,486	97[a]
7	4/28/78	32	3,754	242	991	682[a]	1,560	2,015	3,970	994	243	3,140	5,088	1,090	3,390	3,079	1,962	5,582	121[a]
8	5/30/78	29	2,975	887	2,064	3,450	3,113	2,371	4,184	528	113[a]	3,700	4,485	1,221	3,018	631	1,979	5,059	302[a]
9	6/28/78	30	4,395	714	2,043	3,551	3,468	2,685[b]	3,897[b]	1,436[b]	176[a,b]	4,315[b]	3,671[b]	1,280[b]	1,752[b]	251[a,b]	1,800[b]	3,447[b]	269[a,b]
10	7/28/78	31	2,435	611	1,868	2,775	3,101	2,693	3,247	1,871	138[a]	3,591	3,330	1,416	1,990	183[a]	528	4,194	133[a]
11	8/28/78	31	2,083	1,634[d]	1,982	295[a]	3,083	2,463	3,758	1,775	120[a]	4,933	2,909	573	825	199[a]	717	4,013	94[a]
12	9/28/78	32	2,061	1,845[a,c]	2,067	339[a]	4,286	2,675	5,327	1,865	718[a]	1,939	3,728	1,792	105[a]	186[a]	845	4,511	85[a]
13	10/30/78	29	1,743	779[a]	1,692	1,194[a,d]	5,130	2,100	2,599	1,476	476[a]	1,860	510[a]	1,077	109[a]	176[a]	609[a]	3,513	108[a]
14	11/28/78	36	2,260	905[a]	1,976	669	3,555	2,434	3,642	1,224	610[a]	269	282[a]	1,261	2,687[e]	130[a]	298[a]	4,535	48[a]
15	1/ 3/79	26	1,498	469[a]	1,134	154	1,456	1,529	3,290	2,493	465[a]	1,139[a,e]	696[a]	764	1,643[e]	52[a]	365[a]	4,346	49[a]
16	1/29/79	30	1,844	448[a]	1,303	684	1,619	1,746	1,570	2,708	384[a]	754[e]	1,170[e]	903	1,918[e]	125[a]	309[a]	2,649	181[a]
17	2/28/79	28	1,808	457[a]	1,175	706	1,563	1,528	2,214	1,447	529[a]	2,588[e]	1,214[e]	1,895	2,727[e]	724[e]	414[a]	3,734	180[a]
18	3/28/79	33	1,587	530[a]	766	869	2,176	1,552	1,314	1,603	539[a]	2,961[e]	1,323[e]	2,265	1,825[e]	2,119[e]	1,953[e]	3,289	478[e]
19	4/30/79	29	970[b]	464[a]	1,447	883	2,803	1,446	1,300	1,723	513[a]	2,712[e]	1,530[e]	3,292	1,918[e]	2,655[e]	3,569[e]	3,216	643[e]
20	5/29/79	30	624	762[a]	1,824	2,834	3,505	2,684	235	832	451[a]	2,642[e]	1,623[e]	2,839	1,496[e]	3,195[e]	2,868[e]	4,028	1,698[e]
21	6/28/79	32	2,155	841[e]	3,059	4,149	4,044	4,146	403	2,536	783[a]	3,132[e]	3,732[e]	3,630	3,395[e]	2,526[e]	3,396[e]	3,702	3,247[e]
22	7/30/79	32	1,366	1,364[e]	1,882	2,697	4,457	2,822	488	2,573	486[a]	1,331[e]	2,569[e]	4,195	2,605[e]	4,407[e]	3,915[e]	4,502	2,761[e]
23	8/30/79	31	2,410	1,751[e]	1,964	3,180	4,000	3,353	382	1,905	616[a]	1,669[e]	889[e]	3,892	2,714[e]	4,711[e]	3,282[e]	3,825	3,067[e]
24	10/ 1/79	30	676	1,875[e]	1,083	1,909	2,770	2,160	771	496	329[a]	976[c,e]	2,163[e]	2,349	766[e]	4,249[e]	1,974[e]	4,025	1,791[e]
25	10/31/79	91	6,394	7,629[e]	4,045	6,763	10,842	9,039	10,212	1,411[d]	605[a]	4,388[e]	8,736[e]	9,732	7,027[e]	7,831[e]	8,780[e]	13,731	6,687[e]
26	1/30/80	27	1,749	2,435[e]	1,124	2,343	1,687	2,416	3,593	913	358[a]	1,832[e]	3,733[e]	3,207	1,269[e]	3,777[e]	2,752[e]	3,152	1,817[e]
27	2/28/80	32	2,083	3,160[e]	366	2,593	3,224	641	3,487	663	394[a]	2,007[e]	2,086[e]	3,582	1,398[e]	3,305[e]	3,434[e]	3,823	2,078[e]
28	3/31/80																		
BEFORE FOAMING																			
Total Occupied Consumption			-	-	-	-	-	12,714	21,133	3,315	6,431	25,653	25,396	9,436	22,320	11,133	14,447	31,827	2,898
Total Occupied Days			-	-	-	-	-	224	224	92	195	224	224	224	224	224	224	224	72
Average Consumption/Day			-	-	-	-	-	56.8	94.3	36.0	33.0	114.5	113.4	42.1	99.6	49.7	64.5	142.1	40.2
Average Consumption/Mo			-	-	-	-	-	1,703	2,830	1,081	989	3,436	3,401	1,264	2,989	1,491	1,935	4,262	1,208
Total Average Consumption/Mo			-					2,462						2,317					
Total Consumption ≥990 kW-hr/Mo			-	-	-	-	-	11,399	21,133	2,787	4,795	25,653	25,396	8,038	22,320	8,517	13,670	31,827	1,911
Total Days Consump. ≥990 kW-hr/Mo			-	-	-	-	-	180	224	63	74	224	224	184	224	105	194	224	30
Average Consumption/Day			-	-	-	-	-	63.3	94.3	44.2	64.8	114.5	113.4	43.7	99.6	81.1	70.5	142.1	63.7
Average Consumption/Mo			-	-	-	-	-	1,900	2,830	1,327	1,944	3,436	3,401	1,310	2,989	2,433	2,114	4,262	1,911
Total Average Consumption/Mo			-					2,765						2,694					
AFTER FOAMING																			
Total Occupied Consumption			50,260	30,379	38,052	46,532	71,442	50,112	50,731	30,950	-	44,769	44,433	49,844	37,955	39,139	39,813	82,235	23,789
Total Occupied Days			745	502	794	651	703	642	642	642	-	606	551	642	581	397	493	642	336
Average Consumption/Day			67.5	60.5	47.9	71.5	101.6	78.0	79.0	48.2	-	73.9	80.6	77.6	65.3	98.6	80.8	128.1	70.8
Average Consumption/Mo			2,024	1,815	1,438	2,144	3,049	2,342	2,371	1,446	-	2,216	2,419	2,329	1,960	2,958	2,423	3,843	2,124
Total Average Consumption/Mo			2,091					2,150[f]						2,647[f]					
Total Consumption ≥990 kW-hr/Mo			48,960	26,631	34,723	42,567	71,442	49,471	48,432	26,635	-	42,876	43,517	47,704	36,364	38,415	37,723	82,235	23,146
Total Days Consump. ≥990 kW-hr/Mo			685	336	638	469	703	610	487	430	-	550	520	555	520	369	399	642	307
Average Consumption/Day			71.5	79.2	54.4	90.8	101.6	81.1	99.5	61.9	-	78.0	83.7	86.0	69.9	104.1	94.5	128.1	75.4
Average Consumption/Mo			2,144	2,378	1,633	2,723	3,049	2,433	2,985	1,858	-	2,339	2,510	2,578	2,098	3,123	2,836	3,843	2,262
Total Average Consumption/Mo			2,377					2,437						2,854					

[a] Values not used in averages. Units not occupied.
[b] Units foamed.
[c] Values used in total ≥990 kW-hr/Mo averages.
[d] Values not used in ≥ 990 kW-hr/mo averages.
[e] Units assumed to be occupied.
[f] Averages with assumed occupancy include first month value of assumed occupancy.

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